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ASTRONOMY

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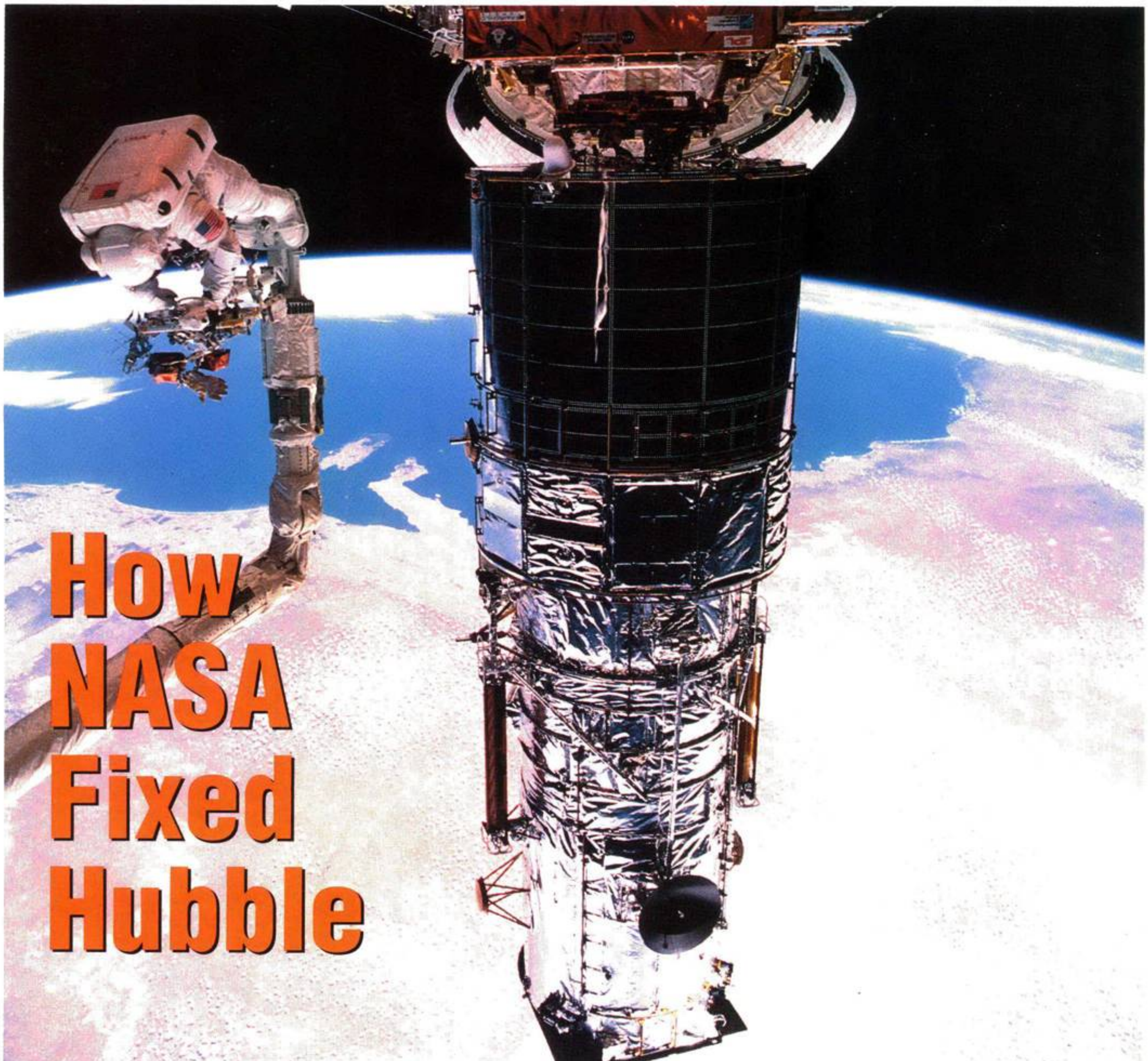

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8" LX200
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Packing & shipping in 48 states: 8"—$105; 10"—$145; 12"—$215.

- **All prices shown are suggested USA mail-order retail prices, exclusive of sales taxes or credit card charges, if applicable.

- For dealer or catalog information see the **Meade Starfinder Reflecting Telescope** ad in this issue.

LX200 SCHMIDT-CASSEGRAINS:
New Technical Advances for 1994.

Six new technical advances that extend Meade's position at the leading edge of telescope technology:

1. 18-volt Dual-Axis Drive Systems—All Meade 8", 10", and 12" LX200's now include **18-volt DC power systems,** superseding the previous 12-volt systems, with the result that **LX200 motor torques are increased by about 60%** over previous models. Combined with new, more efficient DC motor electronics, these powerful, high-torque drives, on both telescope axes, yield a level of drive smoothness heretofore unavailable on any commercial telescope.

2. Ultra-reliable Electronic Systems—Recent electronic refinements in the main circuit boards, the hand controller, and in the control panel electronics have made Meade's new advanced LX200's more reliable than ever before. State-of-the-art improvements in microcircuitry, combined with *thousands* of hours of laboratory and field testing, result in **the most trouble-free serious telescopes ever manufactured.**

3. New *Version 3.20* Software—As recently announced, Meade *Version 3.20* software is the very latest in telescope operating systems and permits **quick (less than 10 seconds!) 2-star alignment** of the LX200 in the altazimuth mode, without requiring your latitude or longitude, without even leveling the tripod. Just use 2 easy-to-find reference stars and the telescope tracks and actuates GO TO with extreme precision.

Meade 8", 10", and 12" LX200 Schmidt-Cassegrains include an RS-232 serial port (PC connector) on the power panel.

MEADE LX200
COMPUTER DRIVE SYSTEM
LX QUARTZ - DC SERVO MOTOR
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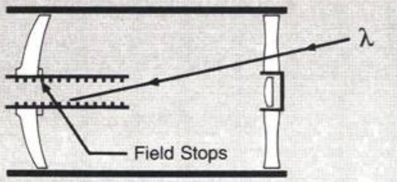
Current (mA x 100)
On
Off
N
S
Encoders
RS232
Focuser
Reticle
Keypad
Power 18vDC
CCD
DEC Motor

4. Software Library Options
Included with every LX200 is a basic 747-object database of the finest deep-space objects, reference stars, and the 8 major planets. *Version 3.20* LX200 software allows for two new optional object libraries:

—**Library Option 1:** An object database of **10,600** celestial objects taken from the Messier, NGC, and IC catalogs. Available at $99.**

—**Library Option 2:** An object database of **64,350** celestial objects, including the 10,600 objects of Library Option 1, above. Available at $149.**

5. PC-Interface Capability
Meade AstroSearch/200™ sky software permits the interface of a personal computer (PC) to your LX200. Just load Meade AstroSearch/200 software into your PC, connect the PC* to the LX200's PC port (located on the telescope's power panel) and you're ready to **point-and-click on any of 45,000 planetary, deep-space, or stellar objects** now visible on the PC display. As you point-and-click, the LX200 slews at high-speed (up to 8°/second) simultaneously on both axes, precisely centering the object in the field of view. **The Meade AstroSearch/200 celestial software package, supplied on 3.5" discs for Windows™ 3.1 or higher, is available from Meade dealers at $99.95**.**



Field-stops *(arrow)*, now included on Meade 8", 10" and 12" Schmidt-Cassegrains, significantly increase image contrast by effectively blocking off-axis stray light rays, λ.

6. Contrast-Enhancing Field Stops—All Meade 8", 10", and 12" Schmidt-Cassegrains now include a series of computer-optimized internal field stops, for greater rejection of unwanted stray light than ever before possible. These field stops, machined into the inside-diameter surface of the primary-mirror baffle tube *(see diagram)*, **significantly increase lunar, planetary, and deep-space image contrast,** compared to SCT's not so equipped.

Plus all of the features that have already made Meade® LX200's the largest-selling serious telescopes in the world:

- **Legendary Meade Super Multi-Coated (EMC) Schmidt-Cassegrain Optics** —The finest SC optics available, optics that yield razor-sharp stellar images and high-resolution observing of the Moon, planets, and deep-space.
- **Heavy-Duty Fork Mounts**—The largest, most rigid in the industry, complemented by large 4"-diameter polar ball bearings and by DC servo-motor-driven worm gears on both telescope axes.
- **Four-speed Drives on both Telescope Axes**—Including photo-guiding (at **2x** sidereal rate); image centering and microslewing in the main telescope (at **32x** sidereal rate); image centering in the viewfinder (at **2**°/sec.); or fast-slew of the main telescope across the skies (at up to **8**°/sec.).
- **Digital Readouts**—On both axes, read from the keypad hand controller.
- **GO TO Capability**—Enter the RA and Dec of an object into the keypad hand controller, press GO TO, and the telescope slews to the object at up to 8°/sec., centering it in the field.
- **747-Object Built-in Library**—Enter any of the 110 Messier objects, 278 of the finest NGC objects, 351 stars (doubles, variables, reference stars), or one of the 8 planets (from Mercury to Pluto), press GO TO, and the telescope slews at up to 8°/sec., centering the object in the field.
- **Permanently Programmable Smart Drive™** —Capable of reducing periodic drive errors to 5 arc. secs. or less, an observatory standard.

Specifications: 8", 10", and 12" LX200's—Each complete telescope includes 8" or 10" (f/6.3 or f/10) or 12" f/10 SC optical tube assembly with super multi-coatings; heavy-duty fork mount with 4" polar ball bearing, dual-axis 5.75" worm gears, and multi-function power panel display on the drive base; manual slow-motion controls on both axes; keypad handheld controller with digital readout display, PPEC Smart Drive, four-speed drive control on both axes, GO TO controller, and 747-object software library; 25 ft. power cord and adapter for telescope operation from 115v.AC (DC capability for operation from auto cigarette lighter plug available optionally); 8 x 50mm viewfinder with crosshairs; 1.25" diagonal prism (8", 10") or 2" diagonal mirror with 1.25" adapter (12"); Series 4000 Super Plössl 26mm eyepiece; standard field tripod (8", 10") or giant field tripod (12"); foam-fitted carrying case; complete operating instructions.

---

*For safety reasons AC-powered personal computers should be used indoors only.

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ASTRONOMY

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Astronauts Work on Hubble

NASA

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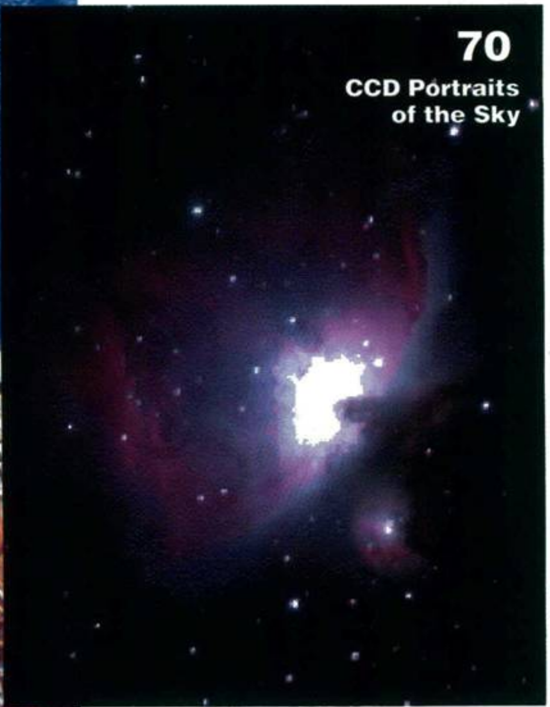

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COVER

Shuttle astronauts Story Musgrave (on the robotic arm) and Jeff Hoffman (in the cargo bay) wrap up five days of arduous spacewalks that put Hubble back on the road to health (see page 26). NASA photo.

BEHIND THE SCENES

Just Do It

If it's springtime, can the plap-plap-plap of running shoes on pavement be far behind? Serious runners pile on the miles all winter, but ordinary folk take to the roads and parks in a more seasonal way. As a result, they pay for the arrival of spring with the burn and ache of muscles stiff from a winter's disuse.

There's another kind of run you can take in springtime, however, and I guarantee it won't leave you with charley horses, sore knees, or a stitch in your side. The name of this run is the Messier Marathon. In this long-distance event you don't pound along neighborhood streets, but instead you jog a course through the sky. Puzzled? The Messier Marathon is the attempt to see — during a single night — every one of the 100-plus galaxies, clusters, and nebulae listed by Charles Messier two centuries ago.

You might think finding these 100-odd objects in a night would be pretty easy — just haul out the scope and a star atlas and get on with it, right? Wrong. First, you can run the Messier Marathon only in springtime because that's when all the objects pass in review between dusk and dawn. Second, it's made even tougher because after you factor in the need for dark skies around the time of New Moon, you're left with only a narrow window of opportunity — and a spell of bad weather can knock you right out of the running. This year, the middle of March is the best time (see page 61).

Unlike a real marathon, the celestial race can have any number of winners. On the other hand, it's plenty competitive too, because you're racing daylight: You and your observing skills go head to head with the relentless rotation of the planet. You can run your marathon alone — or do as most observers do and get together with friends and make a party out of it. As the night rolls on, you'll find you share in the others' little victories and they'll cheer you on, too.

Some purists scoff at the marathon for its headlong style. In truth, the pace can get pretty frantic and you sure won't have much time to savor the sights. During much of the night you'll have only a few moments to locate an object and confirm its identity — and then you're off to the next. (Birders do something like this when they go for a "Big Day," competing to see how many different species they can identify in one 24-hour period.)

The purists aren't totally wrong. Clearly, if all you ever did with your telescope was bag one object after another Marathon-style, you'd miss most of the beauty in the night sky. But running in a Messier Marathon is unsurpassed for limbering up your telescope-handling skills and getting acquainted with the sky. It's also a lot of fun. Is this the year you give it a try? That's for you to decide. But my own opinion is that everyone's observing is much the richer if they go completely gonzo for a few nights once a year.

Just do it.

Sincerely,

Robert Burnham
Editor

LETTERS

Hubble Space Telescope Group Seeks Proposals

The Hubble Space Telescope Amateur Astronomers Working Group announces April 30, 1994, as the postmark deadline for proposals to use HST by amateur astronomers. U. S. citizens or legal residents may request a proposal package from HST Package, AAVSO, 25 Birch Street, Cambridge, MA 02138. Amateurs outside the United States should contact the European director of HST activities at the European Space Agency.

For the purposes of this program, an amateur astronomer is defined as anyone who does not have an advanced degree in astronomy or physics and does not work at an observatory. — *Stephen J. Edberg, HST Amateur Astronomers Working Group, Pasadena, California*

Tunguska's Memory

I greatly enjoyed Christopher Chyba's article on the Tunguska explosion (December 1993). I was particularly struck reading his comments about the possibility of atmospheric explosions occurring without being reported. That reminded me of an incident on September 13, 1992, when I saw a strong yellow flash of light that lasted several seconds and emitted no sound.

A brilliant meteor quickly followed, appearing in several distinct clumps and did not fade across the sky but disappeared behind trees near the horizon. I wonder if what I saw and what other backyard astronomers have occasionally reported might be the end result of the explosion of a meteorite. — *Joan Kuebler, Tiffin, Ohio*

Exposing His Cilm

Noah Romer's letter (December 1993) cites a definition of photography as producing images "by the chemical action of light." CCDs, on the other hand, produce an image by electronic rather than chemical processes.

(continued on page 12)

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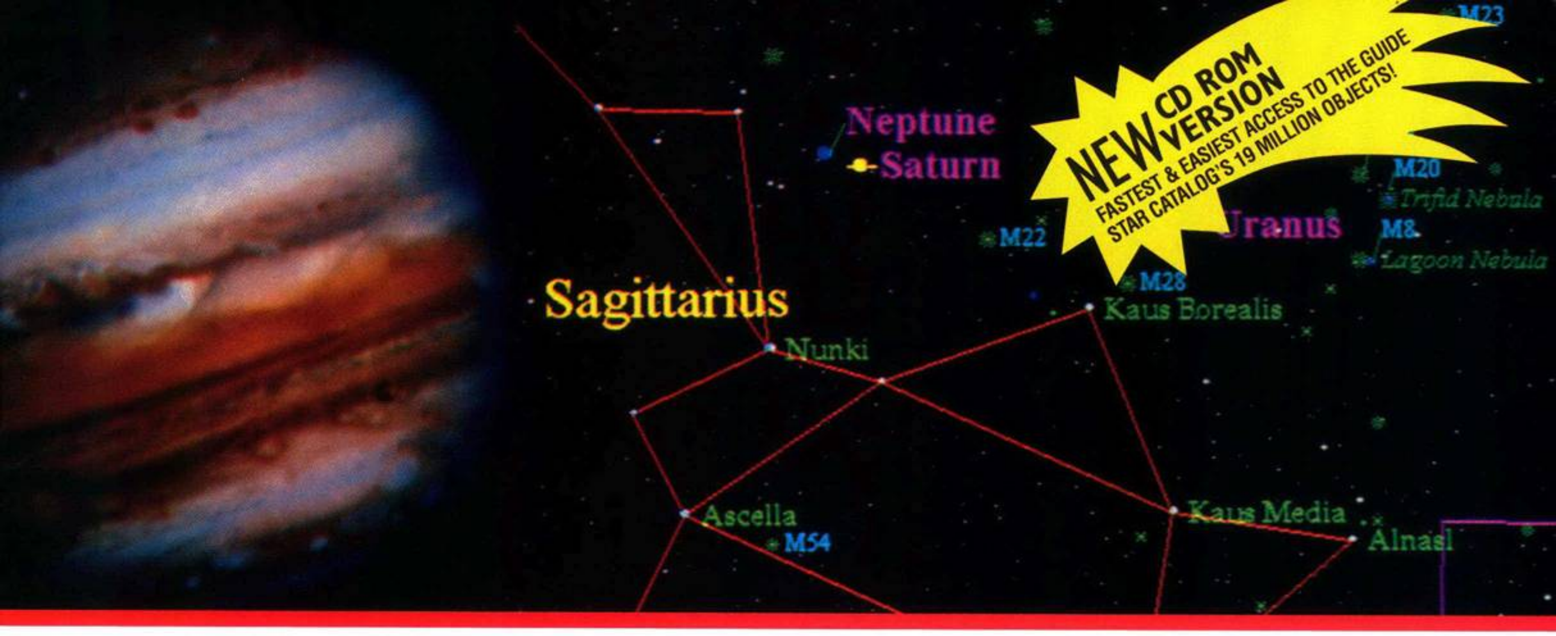
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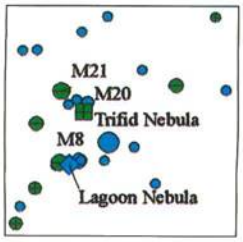
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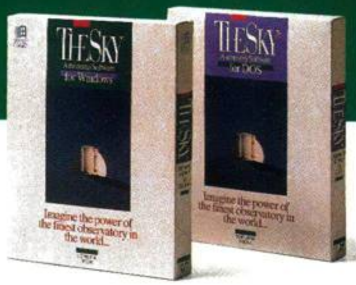
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Through March 31, 1994, at the time you order any Starfinder 6", 8", 10", 12.5", or 16" Dobsonian Telescope, you can buy **two additional Meade multi-coated Modified Achromatic MA9mm and 12mm eyepieces *and* the Meade #637 6 x 30mm coated achromatic viewfinder for a *total* of only $29.95! Purchased separately, the 2 additional eyepieces and viewfinder sell for $109.85!** *(Shown in photo: MA9mm, MA12mm, and standard-equipment MA 25mm eyepieces, with #637 6 x 30mm viewfinder.)*

Starfinder Dobsonian 16

16" f/4.5
$995.

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STARFINDER
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See the Meade General Catalog for details.

Shown with optional 8 x 50mm viewfinder.

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- **Performance!** A Meade Starfinder Dobsonian or Equatorial Telescope opens up the skies to an extremely wide range of serious visual observing: all 110 Messier objects, thousands of NGC objects—nebulae, galaxies, star clusters, in all their variations of form, color, and extent, as well as the Moon and planets in stunning, high-resolution detail. Starfinder Dobsonians are telescopes for visual observing; motor-driven Starfinder Equatorials may be used, in addition, for lunar and planetary photography and even for limited deep-space astrophotography.
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■ **Optional Accessories:** See the Meade accessories ad in this issue. Additional systems, including #55 Manual Declination Control, #43 Drive Corrector, and #47M Dual-Axis Drive Corrector, are described in the Meade General Catalog.

SPECIAL ACCESSORY OFFER! Through March 31, 1994, at the time you order any Starfinder 6", 8", 10", or 16" Equatorial Telescope, you can buy **two additional Meade multi-coated Modified Achromatic MA9mm and 12mm eyepieces for a *total* of only $19.95! Purchased separately, the two additional eyepieces sell for $59.90.** *(Shown in photo: MA9mm, MA12mm, and standard-equipment MA 25mm eyepieces.)*

■ **Packing and UPS Shipping Charges:** to any address in the 48 states: 6"—$65; 8"—$75; 10"—$90. 16"—$55 packing, shipped truck freight collect.

■ All prices shown are suggested USA mail-order retail prices, not including any applicable sales taxes.

■ The **1994 Meade General Catalog**—$3.00 postpaid—is available from any authorized Meade dealer or directly from Meade Instruments.

■ For further information call Meade Instruments at 714-756-2291 or contact one of these authorized mail-order dealers:

Starfinder Equatorial 16

16" f/4.5
$2195.

See the Meade General Catalog for details.

Includes 8 x 50mm viewfinder and giant #682 focuser.

Shown with optional Dual-Axis Drive *Corrector.*

Standard equipment on 6", 8", and 10" models includes:

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Manufactured to exclusive Meade optical designs; threads on to any Meade or Celestron Schmidt-Cassegrain rear cell and converts f/10 scopes to f/6.3 (or f/6.3 SCT's to f/4!), while significantly flattening the field. Use with SCT visual or photo accessories. Actual visual field is increased by 56%, for fine wide-field views of star fields and nebulae. In astrophotography, reduces exposure times by about 50%, while producing an actual field diameter of 1.5" at the film plane. A tremendous aid with CCD imagers in reducing image size for locating and centering images on CCD chips. 4-element optics; multi-coated; 41mm clear aperture. **$129.95** (3.60)

Series 4000™ Super Wide Angle

For exquisite wide-angle images at low-to-medium powers, ideal for star fields, galaxies, and other deep-space phenomena. SWA 13.8, 18, and 24.5mm are superb complements to the #140 Barlow.

Super Wide Angle (SWA; 6-elements; 1.25"; 67°)—**13.8mm: $159.95** (3.49); **18mm: 169.95** (3.69); **24.5mm: 199.95** (3.89); **32mm** (2"): **279.95** (4.78); **40mm** (2"): **339.95** (4.78)

Series 4000™ Ultra Wide Angle

The ultimate eyepieces; extreme image sharpness over an amazing 84° field.

Ultra Wide Angle (UWA; 8-elements; 1.25"; 84°)— **4.7mm: $179.95** (3.29); **6.7mm: 219.95** (3.29); **8.8mm** (1.25"/2"): **269.95** (4.78); **14mm** (1.25"/2"): **329.95** (4.78)

Series 4000™ #140 2x Apochromatic Barlow Lens

The most advanced Barlow Lens available for commercial telescopes; includes 3-element, air-spaced optics, multi-coated. Unmatched in image resolution, contrast, and color correction. Accepts1.25" eyepieces. Lens dia. 28mm; clear aperture 26mm.

$79.95 (3.29)

Meade® Barlow Lens Sale!

Now, through February 28, 1994, buy one of 4 Meade premium-quality Barlow Lenses and save up to 16%. For technical details, see descriptions in this ad.

#140 2x Apochromatic Barlow Lens (1.25"):
Regular Price: $79.95
Sale Price: $67.95. Save 15%.

#122 2x Telenegative Barlow Lens (1.25"):
Regular Price: $47.95
Sale Price: $39.95. Save 16%.

#127 2x - 3x Variable Barlow Lens (1.25"):
Regular Price: $59.95
Sale Price: $49.95. Save 16%.

#126 2x Short-Focus Barlow Lens (1.25"):
Regular Price: $47.95
Sale Price: $39.95. Save 16%.

All prices plus shipping, as noted in product descriptions. This offer is valid between January 20 and February 28, 1994, at participating Meade dealers and is subject to product availability.

Series 3000™ Plössls

The very latest in eyepieces from Meade optical designers, new Meade Series 3000 Plössls yield the finest image corrections obtainable from the classical 4-element Plössl design. Available in a wide range of focal lengths from 5mm through 25mm. All five eyepieces are parfocal, so that, at most, only slight refocusing of the image is necessary from eyepiece to eyepiece. Unlike competing moderately-priced Plössls, Meade Series 3000's are **multi-coated** for maximum light transmission and image contrast. Chrome-plated brass barrels are threaded for standard filters. Manufactured exclusively for Meade Instruments by one of Japan's leading lensmakers, Series 3000 Plössls produce excellent results on reflectors, refractors, and Schmidt-Cassegrains of any focal ratio.

Series 3000 Plössls (4-elements; 1.25"; 50°)
5, 6.7, 9.5, 16, 25mm each: **$59.95** (3.29) **Any 2: $52.95** each;
Any 3: $48.95 each; **Any 4 or 5: $46.95** each.

Series 3000™ Plössl 40mm

A perfect complement to the Series 3000 Plössls at left, this all-new Plössl 40mm produces spectacular low-power, wide-field results with any telescope. Includes classical 4-element Plössl optics, multi-coated. Barrel dia. 1.25", threaded for filters. Apparent field: 44°. **$79.95** (3.79)

Series 4000 Photo-Visual Color Filters (1.25")—Made of purest crown optical glass, dyed in the mass. For increased contrast and resolution on the Moon and planets. Thread into the barrels of virtually all 1.25" eyepieces sold today. Fully coated.

#8 Lt. Yellow; #11 Yellow-Green; #12 Yellow; #21 Orange; #23A Lt. Red; #25A Red; #38A Dark Blue; #47 Violet; #56 Lt. Green; #58 Green; #80A Blue; #82A Lt. Blue. each **$12.95** (2.29)

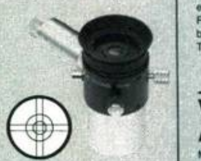
Moon Filter #ND96—Reduces brightness by 87%.	**15.95** 2.29)
Set #1—4 filters: #12, #23A, #58, #80A	**49.95** (2.79)
Set #2—4 filters: #11, #25A, #47, #82A	**49.95** (2.79)
Set #3—4 filters: #8, #21, #38A, #56	**49.95** (2.79)
Sets #1 & #2—8 filters	**89.95** (3.29)
Sets #1, #2, & #3—12 filters	**129.95** (3.48)

#911B
#911N
#910N
#910B
#908B
#908N

Series 4000 Nebular Filters—Premium multi-layer interference filters, the finest obtainable. Use broadband ("B") filters to block most forms of light pollution; use narrowband ("N") filters in heavily light-polluted areas or for extremely high contrast observing of faint nebulae.

#908B—Threads into 1.25" eyepieces; 26mm dia.	**79.95** (2.98)
#910B—Threads into 2" eyepieces; 44mm dia.	**119.95** (3.29)
#911B—Threads on to rear cell of Schmidt-Cassegrain telescopes; 36mm dia.	**99.95** (3.29)
#908N—Threads into 1.25" eyepieces; 26mm dia.	**89.95** (2.98)
#910N—Threads into 2" eyepieces; 44mm dia.	**129.95** (3.29)
#911N—Threads on to rear cell of Schmidt-Cassegrain telescopes; 36mm dia.	**119.95** (3.29)

World's Most Advanced Illuminated Reticle Eyepiece

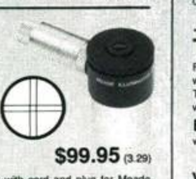


Series 4000 Plössl 9mm, with rubber eyecup and micrometric X-Y positioning of the reticle within the field. Greatly facilitates locking on the guide star. Sharp high-power imaging, excellent eye relief. Wireless red LED illuminator with adjustable brightness control. Internal batteries included. Multi-coated optics. Bullseye reticle. 1.25"

$129.95 (3.29)

Series 4000 Plössl 9mm—Same as above but with 6 ft. cord and plug for Meade LX3, LX5, LX6, LX100, LX200, and APO power panels, in place of wireless illuminator. **$109.95** (3.29)

MA 12mm Illuminated Reticle Eyepiece



Excellent 3-element optical system, long eye relief, fully coated, with double crossline reticle. Includes wireless red LED illuminator with internal batteries and variable brightness control.

$99.95 (3.29)

MA 12mm—Same as above, but with cord and plug for Meade telescopes with power panels, in place of wireless illuminator.

$79.95 (3.29)

2" Diagonal Mirror

#929: Permits use of wide-field 2" oculars. Threads on to rear cell of Meade and Celestron SCT's. Includes multi-coated precision optical flat made at the Meade factory; with 1.25" eyepiece adapter **$99.95** (3.29)

Camera Adapters (1.25" & .965")

Professional-quality adapters for rigid coupling of telescope-to-camera. Use for either Eyepiece-Projection or Prime Focus. Precision-machined of aluminum and brass, threaded for filters. Use with T-Mount, available separately.

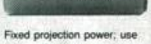
.965": $27.95 (2.79) **1.25": $29.95** (2.79)

Variable-Projection Camera Adapter (1.25")

Machined sliding cell allows variable projection power in eyepiece-projection photography; permits precise selection of correct photo power in lunar and planetary photography; threaded for filters. Use with T-Mount for your camera.

$39.95 (2.79)

Tele-Extenders



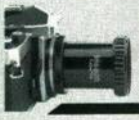
For Eyepiece-Projection photography with any Meade or Celestron SCT. Threads on to eyepiece-holder. Use with T-Mount for your camera.

Basic Tele-Extender: *(above)* Fixed projection power; use with eyepiece for lunar and planetary photos. **$29.95** (2.79)

Variable Tele-Extender: Sliding cell, with lock, permits wide range of projection magnifications with the same eyepiece.

$39.95 (2.79)

T-Adapters for SCT's



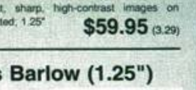
For Prime Focus photography with any Meade or Celestron SCT. Use with T-Mount for your 35mm camera.

$26.95 (2.79)

2X Telenegative Barlow (1.25")

#122: Doubles eyepiece power with sharp, high-resolution, high-contrast imaging on telescopes of all types. 27mm dia. (26mm clear aperture). Excellent corrections for chromatic and spherical aberrations at all photo-visual wavelengths. Multi-coated. 1.25" **$47.95** (3.29)

2x-3x Variable Barlow (1.25")



#127: Precision internal sliding lens assembly permits continuously variable power settings between 2x and 3x. Engraved scale indicates power in use. Yields bright, sharp, high-contrast images on telescopes of all types. Multi-coated; 1.25" **$59.95** (3.29)

2x Short-Focus Barlow (1.25")

#126: Only 2.5" long, the #126 works well with any telescope accepting 1.25" eyepieces, even those with limited focus range. Maintains the high image quality of the #122, above. Insert the #126 into star diagonal for 2x or insert star diagonal into #126 for 3x. 26mm clear aperture. Multi-coated.

$47.95 (2.79)

Modified Achromatic Eyepieces

An improvement on the traditional Kellner design, these 3-element Modified Achromatic eyepieces give sharp, faithful, well-corrected images of the Moon, planets, and deep-space at an economical price. Multi-coated; threaded for filters; 1.25" barrel diameter. Apparent field: 40°. **MA 9, 12, 25, 40mm.**

each: **$29.95** (2.79)

HOW TO ORDER

■ Prices shown are suggested USA mail-order retail prices and do not include any applicable sales taxes.

■ Suggested shipping and handling charges to the 48 states by UPS or US Mail shown in ( ) next to each price.

■ Meade accessories may be ordered from any Meade Advanced Products dealer. **The following national mail-order dealers carry all Meade accessories in-stock for immediate shipment:**

ASTRONOMICS, Norman, OK.
Orders: 800-422-7876; Info.: 405-364-0858.

CALIFORNIA TELESCOPE CO., Burbank, CA
Orders: 800-843-4780; Info: 818-505-8424.

CITY CAMERA, Dearborn, MI.
Orders: 800-359-5085; Info.: 313-846-3922

FOCUS CAMERA, Brooklyn, NY.
Orders: 800-221-0828; Info: 718-436-6262.

LUMICON, Livermore, CA.
Orders: 800-767-9576; Info: 510-447-9570.

SHUTAN CAMERA & VIDEO, Chicago, IL.
Orders: 800-621-2248; Info/IL: 312-332-2000.

Canada:

KHAN SCOPE CENTRE , Toronto, Ontario.
Orders & Information: 416-783-4140.

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ED APOCHROMATIC REFRACTORS

"...Through the Meade 5" Saturn was terrific. Aside from the usual things such as the Cassini Division, I could see the olivine cap on top of the ball, as well as subtle detail in the main equatorial belt. What really struck me as amazing was the true-to-life colour rendition the APO provided. The colour correction of the Meade 5" is as perfect as I've ever seen in a refractor. I can wholeheartedly recommend the Meade 5" APO."—*Richard Anderson, Mississauga, Ontario, Canada*

4" Model 102ED $2195.*

5" Model 127ED $2795.

6" Model 152ED $4495.

7" Model 178ED $5495.

Meade ***ED* super multi-coated objective lenses** yield ultra high resolution, high-contrast images, virtually free of any false color.

LXD 650 (4", 5") and **LXD 750** (6", 7") **equatorial mounts,** new for 1994, *virtually eliminate gear backlash,* resulting in the most rigid, flexure-free mounts available.

Standard accessories include 8 x 50mm viewfinder, 2" diagonal mirror, Super Plössl 26mm eyepiece.

Optional **#1697 Computer Drive System** includes 4 drive speeds on both axes (2x, 32x, 2°/sec., 8°/sec.); Smart Drive™ periodic error corrector; keypad hand controller with digital readouts; automatic GO TO capability from any input RA and Dec or from 747-object library—**$695.** 8000-object CNGC library (a 2-minute plug-in) available separately at **$99.**

Standard Field Tripod (4", 5") and **Giant Field Tripod** (6", 7") provide rock-solid support for the telescope assembly.

Prices listed are for complete ED Apochromatic Refractors, including optical tube assembly with #684 giant 2.7" focuser; 8 x 50mm viewfinder; #930 2" diagonal mirror with 1.25" adapter; Super Plössl 26mm eyepiece; 4" and 5" models include the LXD 650 equatorial mount and standard field tripod; 6" and 7" models include the LXD 750 equatorial mount and giant field tripod; each mount is provided with manual slow-motion controls, analog setting circles, and locks on both axes.

To order, contact your Meade Advanced Products dealer. Packing and shipping in the 48 states: 4"—$105; 5"—$125; 6"—$185; 7"—$215.

*All prices shown are suggested USA mail-order retail prices, exclusive of sales taxes or credit card charges, if applicable.

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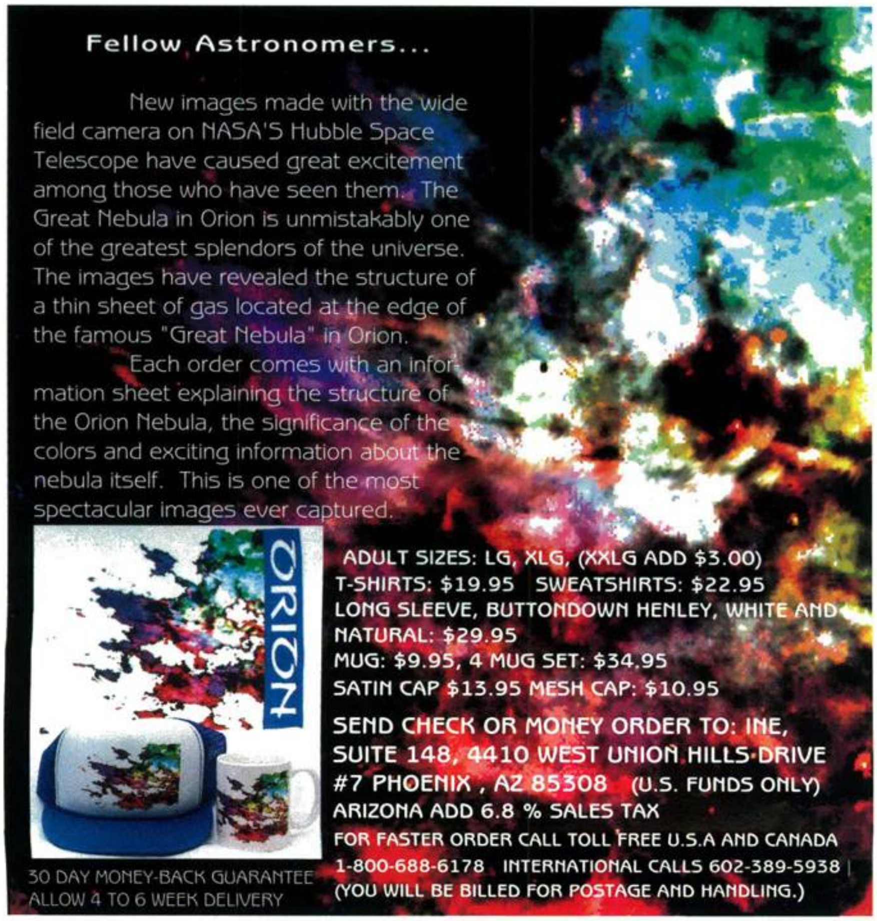
Any questions please call. Toll free: 800-223-1063; in New Jersey: 908-232-1786; Fax: 908-232-3804.



Fellow Astronomers...

New images made with the wide field camera on NASA'S Hubble Space Telescope have caused great excitement among those who have seen them. The Great Nebula in Orion is unmistakably one of the greatest splendors of the universe. The images have revealed the structure of a thin sheet of gas located at the edge of the famous "Great Nebula" in Orion.

Each order comes with an information sheet explaining the structure of the Orion Nebula, the significance of the colors and exciting information about the nebula itself. This is one of the most spectacular images ever captured.

ADULT SIZES: LG, XLG, (XXLG ADD $3.00)
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It's useful to maintain the descriptive difference between electronic and film imaging. But "CCD" is too technical a term for the public, despite its increasing appearances in newspaper ads.

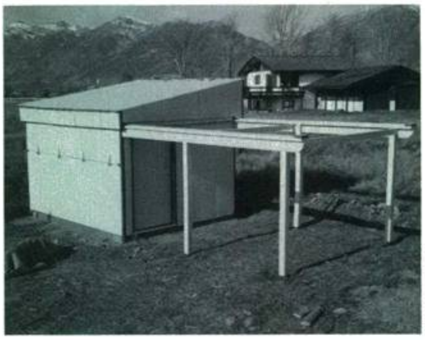
I suggest a new term to describe CCD imaging. Just as "laser" was formed from "maser" with the initial letter standing for light rather than microwaves, I suggest *cilm*, which is formed from film, with the initial letter of CCD replacing the initial letter of film. Cilm is short, catchy, and easy to remember. — *Jay M. Pasachoff, Harvard-Smithsonian Center for Astrophysics, Cambridge, Massachusetts*

Twenty Years of Diversity

Thank you for publishing a comment by Halton Arp in your 20th anniversary issue (August 1993). A free forum for diverse opinions is the lifeblood of science. — *Ira Pilgrim, Laytonville, California*

How I Spent My Summer

Many thanks for your article on building Owl Observatory (April, May, and June 1992). From reading these pieces I got the wild notion that I could build an observatory too. That was both a big mistake and a blessing, but everything came out okay in the end. I spent the summer of 1993 building your roll-off roof design on my property here in Jackson Hole, Wyoming.



Walt Farmer

I made a few modifications from your plan. My building measures 8'x10' on the interior with a single pitched roof. The total cost of materials came to just over $2,200. The instructions in the article were pretty good, although some parts of the diagrams were unclear and you might have provided some guidance on tricky aspects of the construction, such as telling us how to safely cut metal roofing.

In any case, most of the construction is finished and I enclose a photograph of the observatory as of November 1993. — *Walt Farmer, Jackson Hole, Wyoming*

Telescope Credit Cards?

Something struck me the other day as

I was paging through your magazine. I haven't seen one telescope advertisement mentioning any kind of payment plan. Perhaps such an arrangement would make expensive telescopes more easily accessible for beginning backyard skygazers. Besides, virtually every other manufacturing group in America makes it easy to go into debt. Why not telescope companies? — *Roger Lilly, Paoli, Pennsylvania*

Hurrah for Southern Skies

Congratulations on the marvelous article "Exploring the South Polar Sky" by Deborah Byrd (September 1993). It was refreshing to see an article devoted purely to the Southern Sky. This is all too rare. ASTRONOMY is by far the best such magazine available in New Zealand — please let us see more articles with references to the Southern Sky. — *B. C. Askew, Feilding, New Zealand*

Deborah Byrd was especially careful in her description of the globular star cluster 47 Tucanae, which is to most Southern Hemisphere observers more beautiful than its larger cousin, Omega Centauri. I would have liked to see Byrd include another cluster, however — NGC 4755 in Crux, called the Jewel Box. It always draws gasps of delight at star parties under the Southern Sky. — *Mark Nelson, Carnegie, Australia*

— Look for more Southern Sky coverage in coming months.

International Halley Watch Archive

A printed version of the International Halley Watch Archive of Amateur Observations will go to press shortly. Observers who contributed to the IHW and wish to receive a copy of the printed archive should send their names and full mailing addresses to me, either by regular mail, fax at (818) 393-4619, or e-mail at sedberg@gllsvc.span.nasa.gov (Internet). — *Stephen J. Edberg, Jet Propulsion Laboratory, 4800 Oak Grove Drive, Pasadena, CA 91109*

Correction

The photograph on page 47 of the November 1993 issue should have been credited to Alan Johnstone, Mullard Space Science Laboratory. ☐

ASTRONOMY welcomes suggestions and additional information about articles and astronomy in general. Send your letters to ASTRONOMY Letters, P.O. Box 1612, Waukesha, WI 53187. Letters may be edited for length and clarity.

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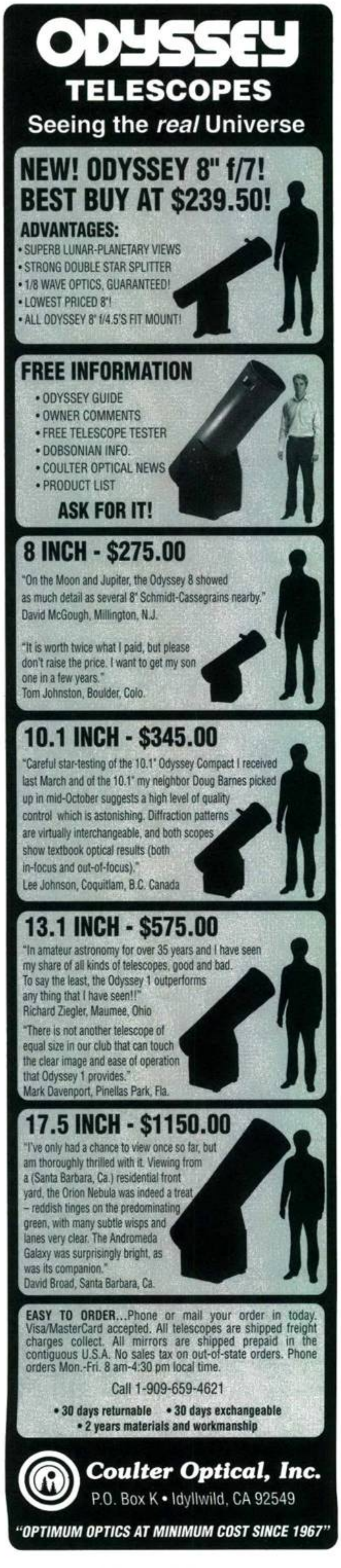

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Tom Johnston, Boulder, Colo.

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"Careful star-testing of the 10.1" Odyssey Compact I received last March and of the 10.1" my neighbor Doug Barnes picked up in mid-October suggests a high level of quality control which is astonishing. Diffraction patterns are virtually interchangeable, and both scopes show textbook optical results (both in-focus and out-of-focus)."
Lee Johnson, Coquitlam, B.C. Canada

13.1 INCH - $575.00
"In amateur astronomy for over 35 years and I have seen my share of all kinds of telescopes, good and bad. To say the least, the Odyssey 1 outperforms any thing that I have seen!!"
Richard Ziegler, Maumee, Ohio
"There is not another telescope of equal size in our club that can touch the clear image and ease of operation that Odyssey 1 provides."
Mark Davenport, Pinellas Park, Fla.

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VIEWPOINTS

Having FITS

by David Bruning

CCD, IMQ, LNX, PDS, PICT, PIX, RAW, SBI, ST4, ST6, TIFF, 08B . . . Today's collection of image formats is a real alphabet soup. And they all have one thing in common: They add to the confusion of astro-imagers and software manufacturers.

A simple solution exists that can slice through this tangle of formats. It's called the flexible image transport system, or FITS for short. It provides a single format that any computer can read.

But few CCD-camera and image-processing programs today use FITS. Instead your image-processing software needs a file-reading utility for every CCD-camera file format so it can translate the gaggle of 0s and 1s on the disk into a stunning image of a deep-sky object. Without the proper decoder, your galaxy image becomes a random collection of light and dark swaths that looks like an abstract painting. Unfortunately, many image-processing programs can read and write files in only a few of the formats listed above. And to make matters worse, file formats have sometimes changed as CCD cameras have evolved.

A program written last year may not be able to read a file created this year with the same file extension. I can't count the number of times my computer balked at opening an image file because a program couldn't recognize the new version of a format — even though I had successfully opened previous files with the "same" format. Another problem is transportability between computer programs. You may be able to read in your image file but can't translate it to the format needed by the program you use to write for the club newsletter or your observing notes.

Some of these incompatibilities arise when software manufacturers loosely interpret the standards for a file format or develop their own subset of the standard. Adding to the confusion is the multitude of standards for some formats: The file changes depending upon whether you use a data-compression scheme or display the image with raster instead of vector graphics. As standards for the file formats evolve, image-processing programs and camera software lose lockstep, until programmers can modify their programs.

These problems with image formats have software developers pulling their hair out too. Too many camera formats and image file formats exist for them to continue to try to support all of them. So what's an astro-imager to do, especially if you use images from different sources?

Professional astronomers long ago solved this problem by adopting a single standard file format. Their problem arose in part from the same conditions facing backyard astronomers today: Too many imaging devices created too many different file formats. And the computers themselves added to the problem because they all had different word lengths for their memories — 8-, 18-, 24-, 36-, 48-, and 60-bit words were common. A computer using 18-bit words couldn't easily read files written by a computer with 60-bit words.

RAW
LNX
FITS
BMP
08B
ST4
CCD
ST6
PICT
PDS
TIFF
SBI
PIX

(A similar problem exists with personal computers today. Most of these computers use 8-bit bytes for their memory word length and assemble longer words from these bytes. Although an 80286-based computer can read and use the 8-bit words of its 8086-based predecessor, an 8086-based computer can't manipulate the 16-bit words of the 80286-based computer.)

The file reading problem first reached a crisis state in radio astronomy. Twenty years ago optical astronomers still used photographic film, but radio astronomers had to store their maps of the sky on magnetic tape. Exchanging tapes between observatories was troublesome because their computers would often have different word lengths. So a group of astronomers created the FITS standard that would enable any astronomer using any computer to read a data tape.

For a number of years, FITS remained a file format that was distinctly radio astronomy. But as optical astronomers started to use CCD cameras, they encountered the same problems the radio astronomers had. Initially each observatory developed a file format for their cameras. But as the cameras became more popular, the researchers again found the proliferation of computer types and file formats bothersome. They discovered the FITS format used by radio astronomers and now generally use this format to record their images.

As image processing has developed, astronomers have required that more information be stored with an image. But instead of changing the FITS standard, they have added to it. To see how this works, let's look at a FITS file.

Each FITS file starts with a header. The header uses 80 character lines, one for each attribute of the image, and uses standard key words to identify each attribute. For example, DATE-OBS identifies the line containing the date of observation, OBJECT describes what was observed, and NAXIS1 and NAXIS2 list the number of rows and columns in the CCD camera chip. Other key words record the type of CCD camera, exposure time, and image processing performed on the image. The program knows when the header ends and the data starts because the last block of lines in the header contains the key word END.

Because the standard can add new key words for the header just as long as it doesn't remove any, astronomers can read an image file created in 1974 just as easily as one written this year. The FITS standard is also device independent, so I can read a file in exactly the same way whether the data came from a Lynxx camera, an ST-6 camera, a spectrometer at Kitt Peak National Observatory, or an instrument on the Hubble Space Telescope.

This versatility of the FITS standard would solve the problems now facing backyard astro-imagers. You would need only a single FITS file utility in your program to read data from a variety of cameras. The program then would know automatically what kind of camera was used and how many rows and columns are in the CCD image. No more "Unknown File Format" messages.

An additional benefit to adopting the FITS standard is the savings to software producers. No longer would they need to spend hours or days writing and rewriting file utilities for their software every time an image or file format changed. They could spend their time — which translates into money you spend on their program — developing new image-processing filters and utilities. Our programs would become more sophisticated rather than more complicated. ☐

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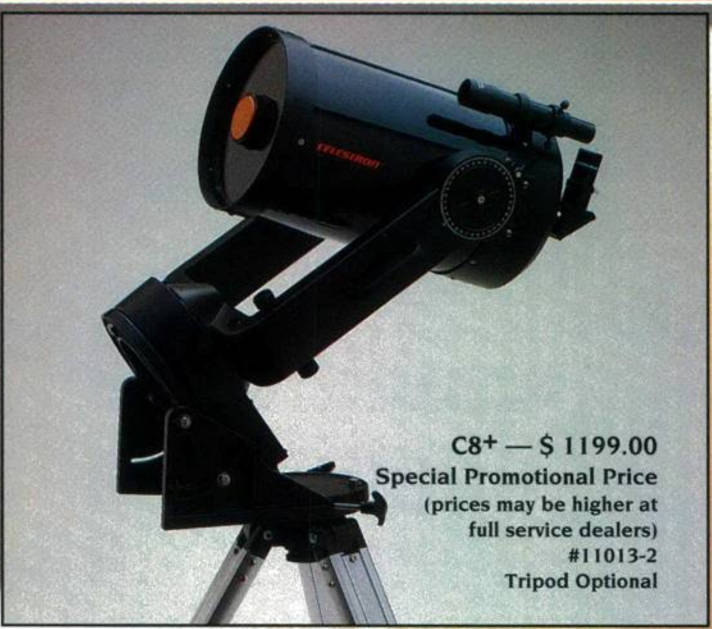

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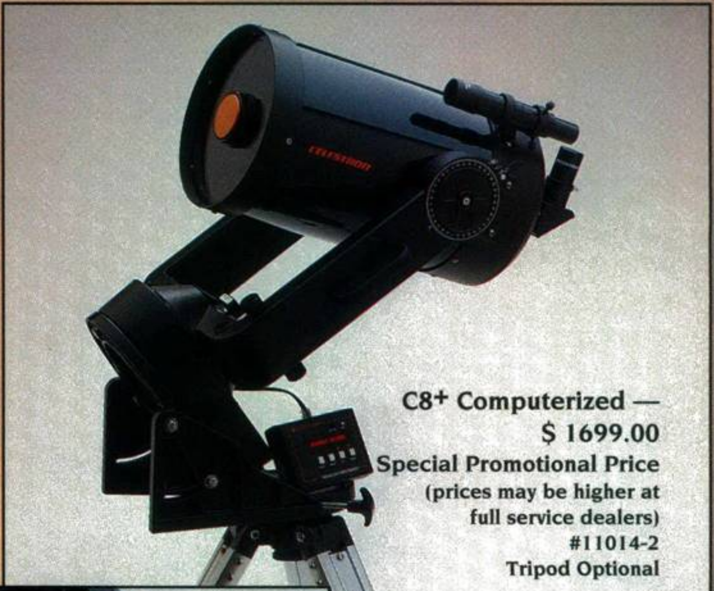

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Hubble Views Distant Interacting Galaxies

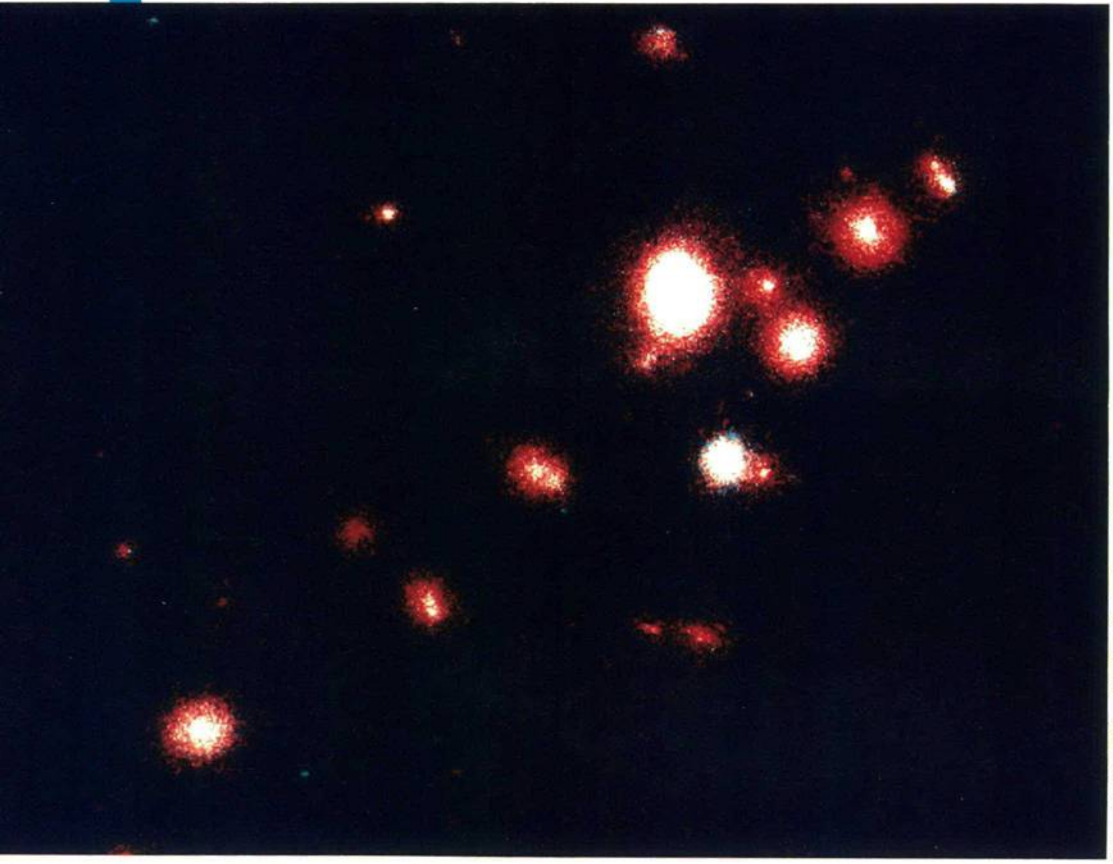
Thanks in part to an electronic glitch on the Hubble Space Telescope, astronomers have discovered a small group of galaxies interacting with one another some 3 billion light-years away. The group hints that interactions and mergers among galaxies may have been common when the universe was much younger.

In the Hubble image, nearly half the galaxies appear to be merging with one another. According to team leader Richard Griffiths of The Johns Hopkins University, "In many of the pairs at least one galaxy is blue, which indicates that star formation is under way at a high rate, possibly triggered by interaction with the neighbor galaxy. Such mergers and interactions may be the rule in galaxy clusters rather than the exception.

"Though the largest galaxy in the image is about the size of our Milky Way Galaxy, most of them are much smaller than our own," he adds. "They might eventually merge to form large galaxies like those we see in the universe at the present day."

Griffiths and his colleagues took the image as part of a random survey. While other astronomers used the telescope to study a bright galaxy, the team was surveying a neighboring patch of sky with the Wide Field Camera. But a malfunction in electronic controls for the solar arrays prevented the arrays from tracking the Sun across the sky. To provide power to HST, mission controllers had the entire telescope roll to keep the arrays pointed at the Sun. It was during this unplanned sweep that the astronomers imaged the distant galaxy group.

GALAXIES INTERACT AND MERGE with one another in a small cluster located some 3 billion light-years away. In many of the pairs at least one member appears to be actively forming stars, a situation possibly triggered by the merger.



Richard Griffiths/Johns Hopkins University and NASA

What Dark Matter *Isn't*

Astronomers believe that unseen matter makes up over 90 percent of the universe, but they don't know what this dark matter is. Some have proposed that it's planets or small faint stars. Others think it's high-energy particles such as neutrinos.

In 1985 physicists reported the discovery of a massive neutrino, named the 17-keV neutrino because its rest mass is 17,000 electron volts. Although this massive particle would help solve the dark matter problem, it posed new problems for cosmologists. Most neutrinos in the universe are light ones that formed when hydrogen atoms fused into helium in the late stages of the Big Bang. But 17-keV neutrinos would have escaped early from the fireball of the Big Bang and would have transformed too much of the Big Bang's energy into mass. The result would be a universe with a much higher mass than astronomers measure.

While cosmologists were scratching their heads about this new puzzle, physicists tried to reobserve the particle. As reported by Douglas Morrison in the November 4 issue of *Nature*, physicists concluded this year that the particle doesn't exist. Without a 17-keV neutrino, astronomers no longer have to worry about their measurements of the total mass of the universe. Although the nature of the dark matter remains a mystery, they now know one more thing it isn't.

Titan Surface Features Detected

Two groups of researchers working at near-infrared wavelengths report that they have detected the surface of Titan, which is hidden by smog at visual wavelengths. Their findings indicate that Titan, the largest moon of Saturn, rotates synchronously (once on its axis for each orbit around Saturn). The results also point the way toward imaging the surface in more detail, both from Earth and by way of future spacecraft.

The first group — Mark Lemmon, Erich Karkoschka, and Martin Tomasko of the University of Arizona's Lunar

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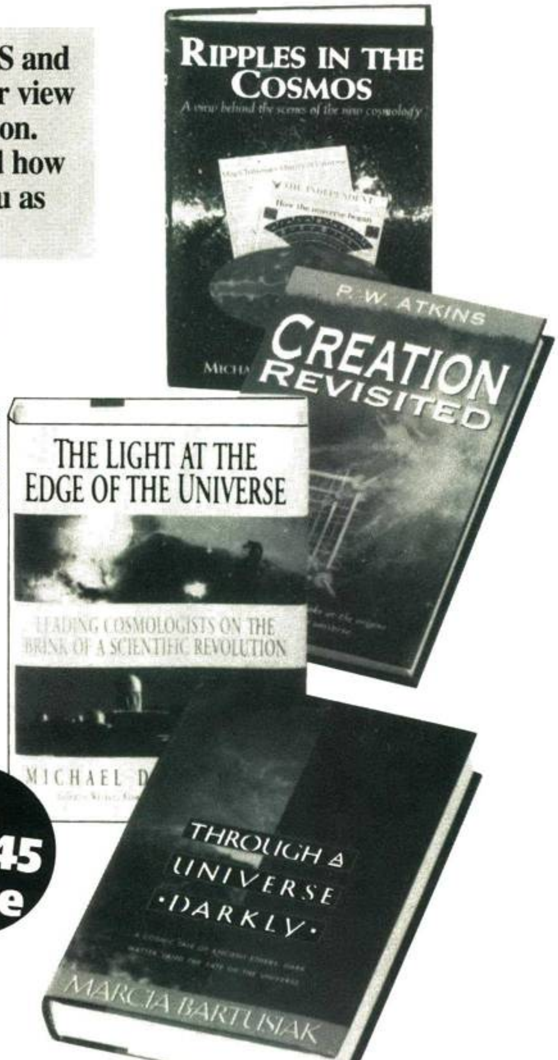
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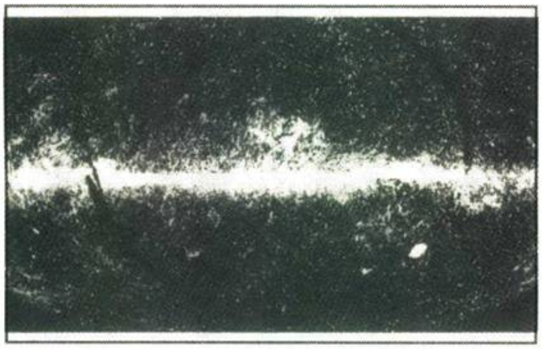

The distribution on the sky of the infrared sources detected in the IRAS survey. The sources concentrated towards the plane of the Milky Way are stars and dust clouds where new stars are forming. Away from the Milky Way, most of the sources are distant galaxies.

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and Planetary Laboratory — observed Titan once when it lay east and once west of Saturn. They found Titan's leading hemisphere was 10 percent brighter when viewed at certain infrared wavelengths. Writing in the June 1993 *Icarus*, they interpreted the brightness difference to be either a surface feature or a cloud at low altitude.

Working in the same spectral "windows," Caitlin Griffith (of NASA's Ames Research Center) observed Titan during two orbital cycles. Writing in the August 5, 1993 *Nature*, she confirmed the hemispheric brightness difference and found that it indeed changes in the same time that Titan revolves around Saturn. Thus she showed that the technique allows astronomers to detect the moon's surface. She also showed that Titan, whose rotation period was unknown, in fact rotates synchronously.

In the coming year the researchers hope to use these infrared wavelengths to image Titan in greater detail and try to learn more about its still-mysterious surface. Looking further into the future, the Cassini Saturn-orbiting spacecraft (due for launch in 1997) will carry two instruments able to view the moon at the same wavelengths from close up.

Novae Erupt in Cassiopeia, Sagittarius, and Lupus

On December 7, 1993, amateur astronomer Kazuyoshi Kanatsu photographed the constellation Cassiopeia and captured a magnitude 6.5 nova. Nova Cassiopeiae 1993 is located at 23h42m, +57.5° (epoch 2000). Peter Collins of Scottsdale, Arizona, reported an independent discovery of the object on December 13. As of December 16 the new star seemed to be holding steady in brightness.

On August 27, 1993, two astronomers independently discovered a nova in the constellation Sagittarius. Using photographic equipment, William Liller of Viña del Mar, Chile, and Matsuo Sugano of Minami-Oda, Hyogo, Japan, recorded an anomalous star at 18h12m49s, −29°29'04" (epoch 2000). Designated Nova Sagittarii 1993, the star at magnitude 11.5.

By October 4 the nova had faded to magnitude 10.3. Meanwhile, on September 19 Liller discovered another nova, this one an 8th-magnitude star in the southern constellation Lupus. Nova Lupi 1993 (epoch 2000 position: 14h28.4m, −50°57') faded slowly in the ensuing weeks.

Protogalaxy Found

A galaxy passing nearby can pull a long tail of material from another galaxy. For the last 50 years astronomers have suspected that a dwarf galaxy can form from this debris. Now they have observations of such a galaxy forming.

Christian Henkel of the Max-Planck-Institut für Radioastronomie in Bonn, Germany, and colleagues in Heidelberg, France, and the United States found this protogalaxy near M81 in Ursa Major from its radio signature. The protogalaxy is not visible in optical telescopes because dust and gas mask the bright stars. The astronomers estimate the galaxy may be only 1,000 light-years across and about a million times less massive than our Galaxy.

Gamma-Ray Bursts from Comets?

Later this year, Comet Shoemaker-Levy 9 will smash into the planet Jupiter, creating a visual feast for observers on Earth. Some astronomers think a similar though much more violent mechanism may produce one of astronomy's great enigmas — the short, intense bursts of gamma rays that rain down on Earth from beyond the solar system. (See "A Burst of Gamma Rays," October 1991 and "Bursting with Surprises," March 1992). They speculate that these gamma-ray bursts arise when comets collide with neutron stars.

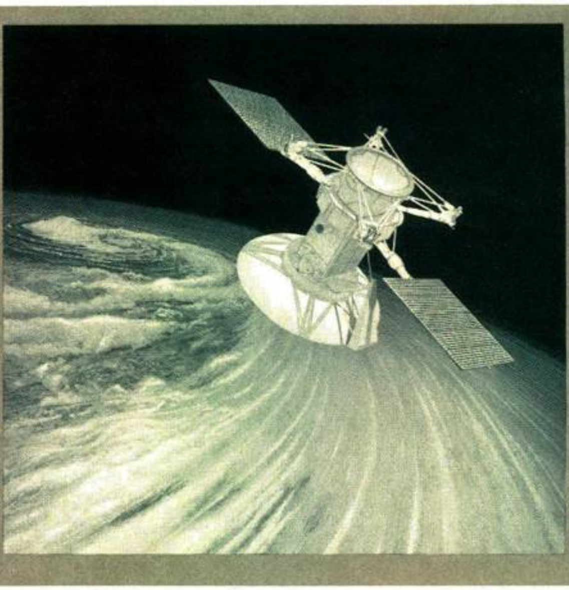
Now Alan Stern of the Southwest Research Institute and Michael Shull of the Joint Institute for Laboratory Astrophysics have added a new twist to this scenario. In the past, astronomers envisioned the bursts arising either when a neutron star captures and destroys a comet from its own Oort cloud or when the supernova explosion that creates a neutron star flings the star through its Oort cloud. Now Stern and Shull have calculated that a hundred times as many gamma-ray bursts should arise from neutron stars traveling through the Galaxy and running into the Oort clouds surrounding other stars.

Although this mechanism theoretically could produce gamma-ray bursts, Stern and Shull admit that the number of bursts observed falls well short of the number they calculate should occur. They conclude that either gamma-

Magellan Completes Aerobraking

On August 3, the Magellan Venus orbiter completed the first aerobraking maneuver ever conducted by a space probe. For 70 days the orbiter dipped through the upper atmosphere of Venus once each orbit, using the braking effect of atmospheric drag to change its orbit from its original 300 by 8,500-kilometer elliptical orbit to a 197 by 541-km orbit.

Magellan completed its prime mission, radar mapping, on September 14, 1992, and is now mapping the gravitational field of Venus, obtaining data that should provide a picture of what lies beneath the surface of the hothouse planet. Magellan first mapped the gravity near the equator of the planet. Now, thanks to aerobraking, Magellan's new lower orbit will allow mission scientists to map the strength of Venus' gravity over the midlatitude and polar regions.



MAGELLAN'S NEW ORBIT allows it to map variations in the strength of Venus' gravity from place to place, providing clues about the interior of the planet.

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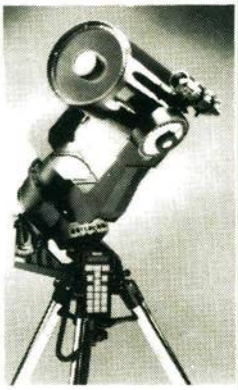

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ray bursts don't arise from comets hitting neutron stars or that the fraction of stars in the Galaxy with Oort clouds is only about 15 percent.

A New Age for the Universe?

Hubble's constant measures how fast the universe expands and is probably the most contested number in astronomy. Some astronomers say it is about 15 km per second per million light-years, while others claim it is higher, 23 km/s per million light-years. Two new studies provide yet another answer: about 11 km/s per million light-years.

Michael Jones of the Mullard Radio Astronomy Observatory in England and his colleagues reported in the September 23 issue of *Nature* that they observed distortions of the cosmic background radiation created by hot gas in the galaxy cluster Abell 2218. Initial analysis of their data implied a Hubble constant of around 15. But at the October 1993 meeting of the Royal Astronomical Society, the group reported that additional data indicate the Hubble constant is under 12 km/s per million light-years.

Joseph Lehar of the Institute of Astronomy in England and his group also find a value of 11 km/s per million light years. They looked at the changes in the brightness of distant quasars that are lensed by the gravity of intervening galaxies. This value of the Hubble constant implies that the universe could be 25 billion years old. If correct, this new value would remove the paradox between the age of the universe found from galaxies and that found from stars (see "The Age Paradox," June 1993).

ROSETTA Gets the Go-Ahead

The European Space Agency announced in November that the comet rendezvous mission called ROSETTA would form the third cornerstone of its Horizon 2000 program. ESA also confirmed that FIRST, the Far Infrared Space Telescope, would be the fourth cornerstone.

Scheduled for launch in 2003, ROSETTA will fly by Earth and either Mars or Venus to gain enough speed to reach the comet near the farthest point in its orbit around the Sun. (If the launch takes place between 2002 and 2004, potential targets include Schwassmann-Wachmann 3, Wirtanen, Finlay, and Brooks 2.) The spacecraft will then travel with the comet as it heads toward the Sun, studying the cometary material and how the comet evolves with decreasing distance from the Sun. The mission will also deploy a probe on the comet's surface to study the nucleus. ROSETTA will also visit one or two asteroids on its circuitous journey to the comet.

FIRST will be launched into Earth orbit in 2006. It will consist of a 3-meter telescope and a sophisticated array of coolers and detectors designed to probe molecular clouds, warm dust, and extragalactic objects.

AMATEUR NEWS

Astronomers Win Waste Lighting Battle

A year and a half after the approval of what is believed to be the first Ohio law to control light pollution, it appears the controls might be having some positive effect. Liberty Township in Delaware County, about 20 miles north of Columbus, now requires that all outdoor night lighting be fully shielded and directed toward the ground. In addition, the regulations require that lighting not used for security purposes or by an open business be turned off by 11:00 p.m.

There was opposition to the regulations. To counter this, Robert Dixon, assistant director of the Ohio State University radio telescope, gave talks to local groups and at public hearings. He has high praise for a set of light-pollution slides distributed by the Astronomical Society of the Pacific and the International Dark-Sky Association. "I could have talked and talked, but until people saw the slides, they really didn't understand the problem. The slides are very convincing."

Tom Burns, assistant director of the Perkins Observatory located in the township, said the builders of a shopping center were particularly wary of the restrictions. "But once we explained how using fully shielded lights and reducing the number of lights could save them money, they decided it was a good idea." To learn more about how you can help reduce waste lighting, contact the International Dark-Sky Association at 3545 North Stewart, Tucson, AZ 85716.
— *Robert Bunge*

Space Center Opens in New York

June 11, 1993, witnessed the dedication of the Kopernik Space Education Center in Vestal, New York. The new facility is a state-of-the-art educational complex that houses a museum, observatory, science classrooms, an auditorium, and a meeting place for the Kopernik Astronomical Society. The building's equipment includes a 20-inch Ritchey-Chretien telescope, a 14-inch SCT, a 12.5-inch Tinsley Cassegrain, and a 6-inch refractor.

"The center is the only science facility of its kind in which amateur astronomers played a significant role in its development," says Jay Edwards, president of the Kopernik Astronomical Society. Club members helped with the planning and fundraising that resulted in one of the best science centers in the United States.

For more information about the facility, contact E. Jay Sarton, Director, Kopernik Space Education Center, Underwood Road, Vestal, NY 13850 (607) 748-3685.

Planet Walk Opens in Lansing

On October 19, 1993, a coalition of organizations in Lansing, Michigan, dedicated a walk through space right in their backyard. Civic groups planned and constructed the Planet Walk, a reconstruction of the solar system to scale placed along Lansing's River Trail, which borders the Grand and Red Cedar Rivers. Skylab and Shuttle astronaut Jack Lousma helped dedicate the trail on its inaugural day. Numerous visitors have already walked the length of the solar system in about 45 minutes.

As visitors stroll along the Planet Walk, they traverse one million miles of the solar system's diameter with each step. The model of the Sun, spanning 20 inches across, sets the scale for the rest of the solar system's inhabitants scattered along 7,000 feet of trail. Earth is 179 feet away and spans the size of a pencil eraser.

READER'S EXCHANGE

FOR SALE. *Astro-Metrics of Undiscovered Planets and Intelligent Life Forms*. Limited edition, 354 pages; $24.95. Available March 1994. Order from D&L Associates, P.O. Box 2851, Sunnyvale, CA 94087.

WANTED. Thin 40" mirror blank. Pregenerated curve is okay. Contact John Sherman, 16037 Parthenia Street, North Hills, CA 91343.

FOR SALE. 8x50 finderscope and mounting bracket for orange tube C8; $55. Counterweight set for C8; $45. Wil Tirion *Sky Atlas 2000.0*, 26-section field edition; $20. All in excellent condition and postage paid. Contact Omar Zuhdi, 2303 Robinwood Place, Shawnee, OK 74801, (405) 275-6052.

FOR SALE. 12.5 mm Plössl illuminated reticle eyepiece, used once, 1.25" O.D. new condition; $50 or best offer. Contact David Green, 7035 Vandike Street, Philadelphia, PA 19135, (215) 333-7842.

FOR SALE. For information about radio astronomy contact Vincent Caracci, Society of Amateur Radio Astronomers, 247 N. Linden Street, Massapequa, NY 11758.

FOR SALE. Questar 7" telescope, Pyrex mirror, Barrell and control assembly, equatorial mount, sun filter, eyepieces, camera, and coupling; $5,500. Contact Joan Fuhrman, (201)-692-1366.

FOR SALE. 10" Meade Schmidt-Cassegrain telescope. Many accessories and in good condition; $1,750. Contact 1528 N. Seminary Avenue, Apt. G, Woodstock, IL 60098, (815) 337-8533.

WANTED. Information, copies of instruction books, and parts lists for Bausch & Lomb 4000 SC scope. Contact Harry Ditmore, (208) 436-6818.

FOR SALE. ASTRONOMY back issues (May 1987-present), all in mint condition; $50 plus postage. Contact B. Derochi, P.O. Box 1015, Cherokee Village, AR 72525, (501) 257-2308.

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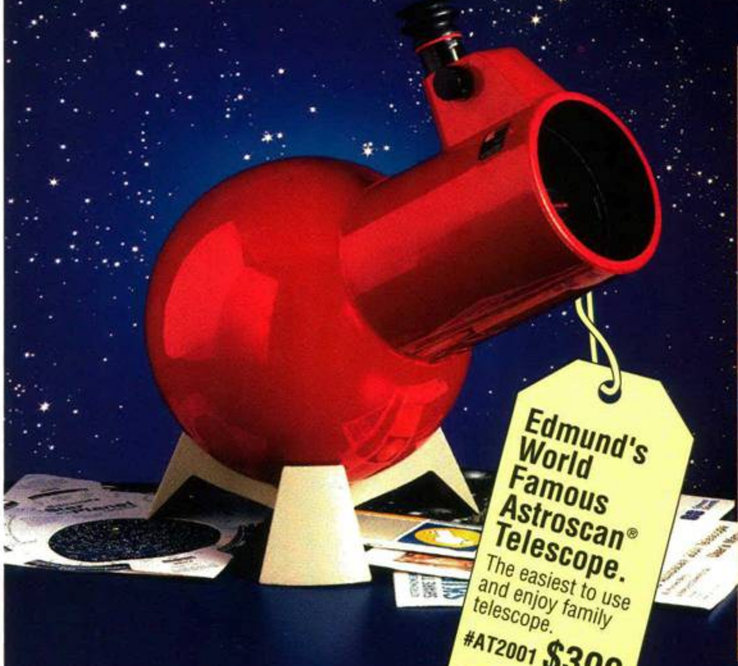
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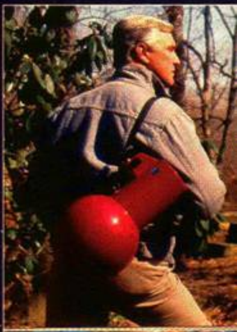

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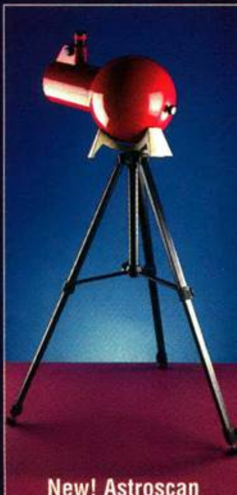

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Russian Mars Probe May Be Delayed

Rampant inflation and sticky technical problems may push back the launch of Russia's Mars '94 mission two years. If the launch slips past the currently scheduled November 1994 date, the ambitious mission will have to wait until 1996, when Earth and Mars are once again close together. (See "Mars: The Russians Are Going!", October 1993, for details on the mission.)

Lack of funds seems to be the biggest problem facing Mars '94. With inflation in Russia running at an annual rate of some 300 percent, the money originally earmarked for the project is quickly evaporating. In addition to the money squeeze, problems have also cropped up in the development of a crucial scan platform.

If the Russians can't launch in 1994, they may try to send both the Mars '94 and the Mars '96 spacecraft during the 1996 launch window. However, further money problems could push the Mars '96 rover mission back to 1998.

A Critical Universe

Is the universe open and destined to expand forever or is it closed and doomed to fall back onto itself? This is one of the fundamental questions facing astronomers today. The factor that will determine the fate of the universe is the density of matter: High density means the universe is closed and low density means it is open. Most astronomers believe in an inflationary model of the universe, which predicts that the density is close to the critical value that separates these two outcomes.

This belief has obtained support recently from a study of 82 compact radio sources made by Kenneth Kellerman of the National Radio Astronomy Observatory. He plotted the size of the sources versus the speed they are moving away from us, which is a measure of the objects' distances. Kellerman found that the density is almost exactly the critical value, consistent with the prediction of inflationary models.

ESA

BREAKING THE LATITUDE RECORD held by Voyager 1, Ulysses passed a latitude of 32° below the Sun's equator on June 9. Ulysses is a European Space Agency and NASA satellite (shown here before launch) designed to explore the polar regions of the Sun and solar system. Just as Ulysses passed the 32° mark, the probe signaled that it had entered the region above the permanent polar hole in the Sun's outer atmosphere, the corona, and was now detecting magnetic fields and particles streaming directly from the pole.

Farthest Hydrogen Cloud in Our Galaxy

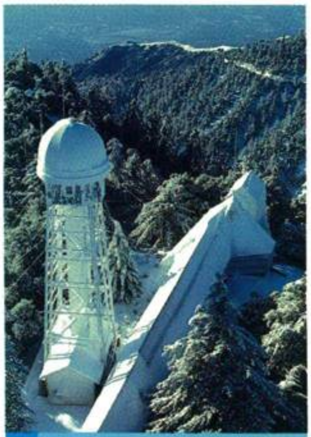
Astronomers see stars in the disk of our Milky Way Galaxy out to about 60,000 light-years from the Galaxy's center. Beyond this stellar disk they can trace atomic hydrogen out another 40,000 light-years. But they thought the atomic hydrogen gas was too thin to form stars and that the molecular hydrogen gas clouds in which stars form exist only within the stellar disk.

Now Eugene De Geus of the University of Maryland and his research team have found a molecular hydrogen cloud in Cassiopeia. The cloud, illuminated by a hot B-type supergiant, lies 90,000 light-years from the center of the Galaxy. The astronomers suggest that other clouds exist outside the stellar disk but that we don't see them because a hot star isn't presently lighting them up.

Alexis Lives!

No, it's not a character from a prime time TV soap opera. ALEXIS is the Array of Low-Energy X-ray Imaging Sensors, a $17 million X-ray satellite built by the Los Alamos National Laboratory. Although built to test new X-ray sensors for detecting nuclear weapons, ALEXIS' X-ray eyes can focus low-energy or "soft" X rays coming from a 30°-wide area of the sky.

But shortly after ALEXIS' April 25, 1993 launch, scientists doubted whether these telescopes would ever get the chance to probe the universe. A mishap during its launch from an Air Force Pegasus booster apparently had damaged a solar panel and sent the craft out of control. Then in the summer of 1993, ground controllers managed to contact the craft and stabilize it. In late July, Los Alamos scientists powered up one of the X-ray telescopes and "saw" first light, a remarkable recovery for a spacecraft that had been all but written off. □


Mount Wilson Observatory Association

NINETY YEARS YOUNG, the Snow Telescope has entered a new chapter in its career of solar observing. After a year of service at Yerkes Observatory in Williams Bay, Wisconsin, the Snow became Mount Wilson's first permanent telescope in 1904. The Mount Wilson Institute rededicated the scope in October 1993 as part of the institute's Telescopes in Education program. (For more information about this program, write the Mount Wilson Institute, 740 Holladay Road, Pasadena, CA 91106.)

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Aperture	Mounted	Aperture	Unmounted
2.4"	$49.00	2.4"	$39.00
3.1"	52.00	3.1"	42.00
3.5" to 4"	59.00	3.5 to 4"	49.00
4-1/4" to 5"	74.00	4-1/4" to 5"	64.00
6"	79.00	6"	69.00
8"	95.00	8"	85.00
10"	109.00	10"	99.00
11"	119.00	11"	109.00
12.5" to 13.1"	149.00	12.5" to 13.1"	129.00
14"	169.00	14"	149.00

40mm to 80mm Binoculars - Mounted .... $92.00 pr.

GLASS (Full Aperture) Type 2

Same as type 1, except stainless steel is combined in the coating to provide an even more durable surface that highly resists wear due to excessive handling and ultraviolet radiation. Solar image is also yellow-orange.

Aperture	Mounted	Aperture	Unmounted
2.4"	$62.00	2.4"	$52.00
3.1"	65.00	3.1"	55.00
3.5" to 4"	76.00	3.5 to 4"	66.00
4-1/4" to 5"	96.00	4-1/4" to 5"	86.00
6"	105.00	6"	95.00
8"	125.00	8"	109.00
10"	139.00	10"	129.00
11"	149.00	11"	139.00
12.5" to 13.1"	179.00	12.5" to 13.1"	159.00
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3.5" to 4"	99.00	3.5 to 4"	79.00
4-1/4" to 5"	125.00	4-1/4" to 5"	110.00
6"	135.00	6"	115.00
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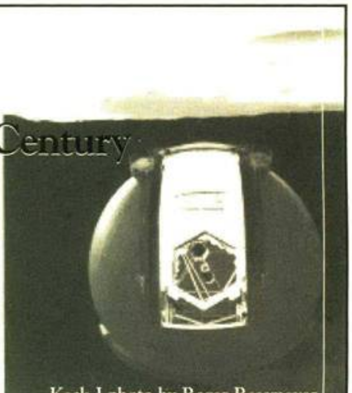

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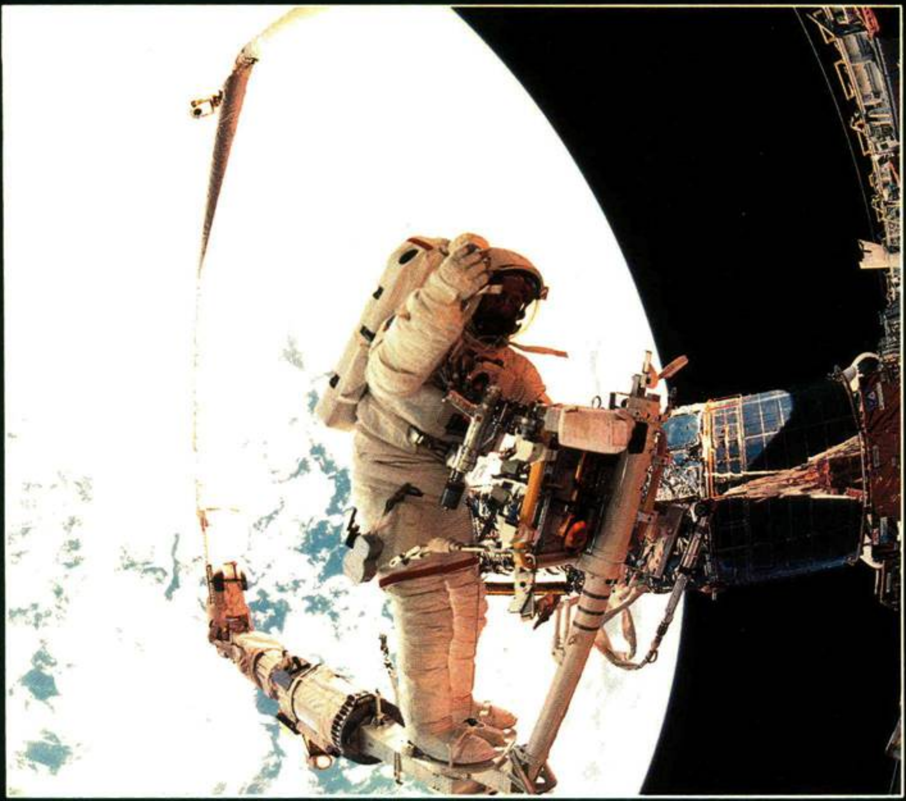


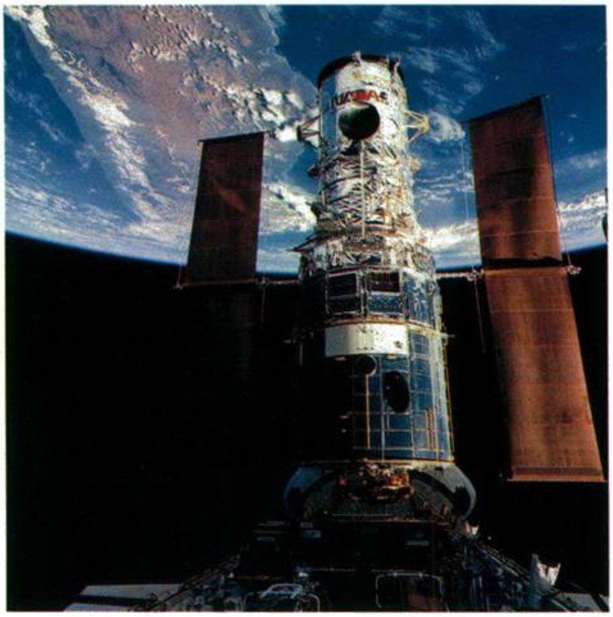
Putting Hubble Right

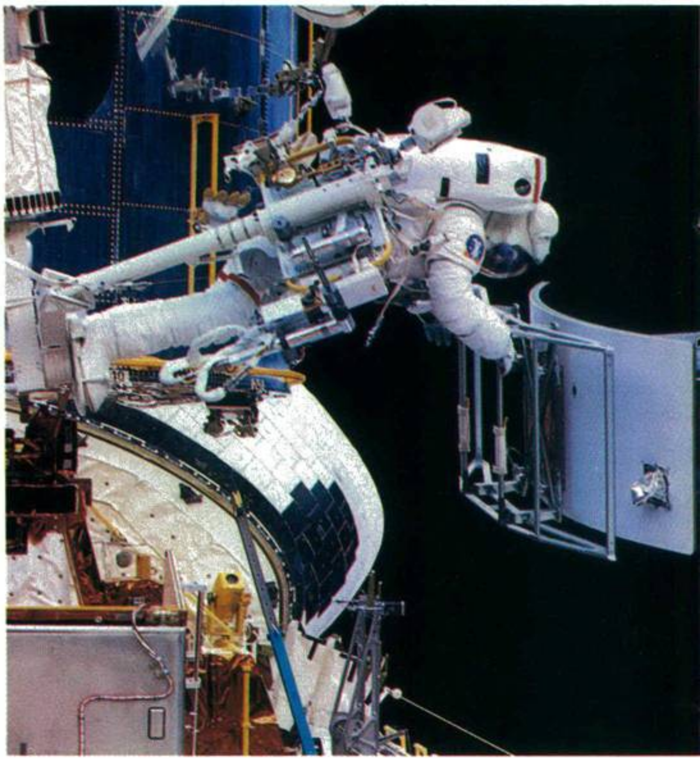
The crew of Endeavour replaced gyroscopes, solar arrays, and scientific instruments. And, everyone hopes, fixed its blurry vision.

by Richard Talcott

ROCKETING INTO SPACE on December 2 (above), seven astronauts set off to repair the Hubble Space Telescope. On the third spacewalk, Jeff Hoffman (top) directs Claude Nicollier's movement of the robot arm. After servicing (right), Hubble awaits deployment. NASA photos.

JPL





AFTER CAPTURING HUBBLE, the Endeavour crew surveyed the orbiting telescope and the kink in one of the solar panel's support booms (above left). Claude Nicollier watches two spacewalking astronauts as he controls the shuttle's robot arm (below). Jeff Hoffman and Story Musgrave prepare to install WF/PC II into the empty cavity (right) created by the removal of its predecessor, WF/PC I (above).

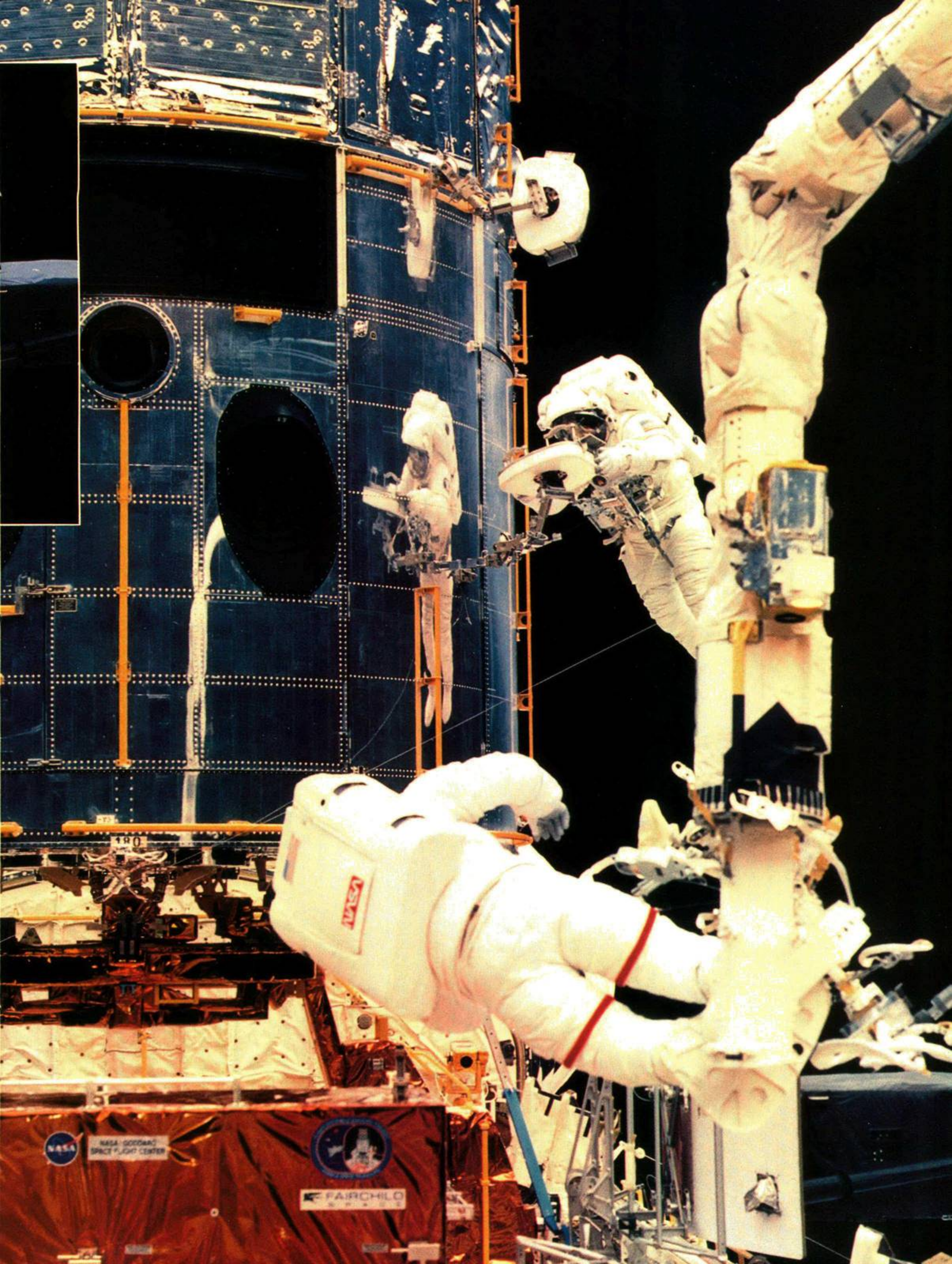
A quick check of the calendar proved I wasn't dreaming — it really was 1993 and not 1969. But similarities to that bygone era were powerful nonetheless. The space program was back in the news, leading the nightly network newscasts and garnering front-page coverage in newspapers across the country. And the reports were not of a failure or mishap like so many in NASA's recent history, but of a triumph of surprising proportions.

The seven astronauts on board the space shuttle Endeavour managed to grab hold of the ailing Hubble Space Telescope, lock it down in the shuttle's payload bay, and repair or replace several malfunctioning systems during an ambitious series of five spacewalks. And they made it look easy. The only question remaining after the mission is whether the fixes designed to correct HST's blurry vision will work. An answer to that should come in late January.

The servicing mission got off to an auspicious start when Endeavour rocketed into space during the early morning hours of December 2. NASA had little choice but to go with the decidedly non-prime-time launch — HST's orbit put the telescope in a position where the shuttle could catch it only if it were launched within a 1-hour window in the *morning*. The early launch set the tone for the entire mission, with the astronauts working at night and sleeping during the day (at least according to time in the United States). Although the schedule kept the crew alert for their strenuous space activities, it left a nation of bleary-eyed space enthusiasts on the ground.

For two days pilot Ken Bowersox and mission commander Dick Covey slowly closed the gap between Endeavour and Hubble. As Covey maneuvered the shuttle close to HST, Swiss astronaut Claude Nicollier plucked the orbiting telescope from space with the shuttle's robotic arm, which he operated during most of the mission. The ease with which he grappled the observatory and placed it on a special turntable at the back of the cargo bay boded well for the rest of the mission. It also spoke well of NASA's decision to make Hubble "astronaut friendly," a point driven home several times during the course of the mission.

As the shuttle approached HST, the astronauts could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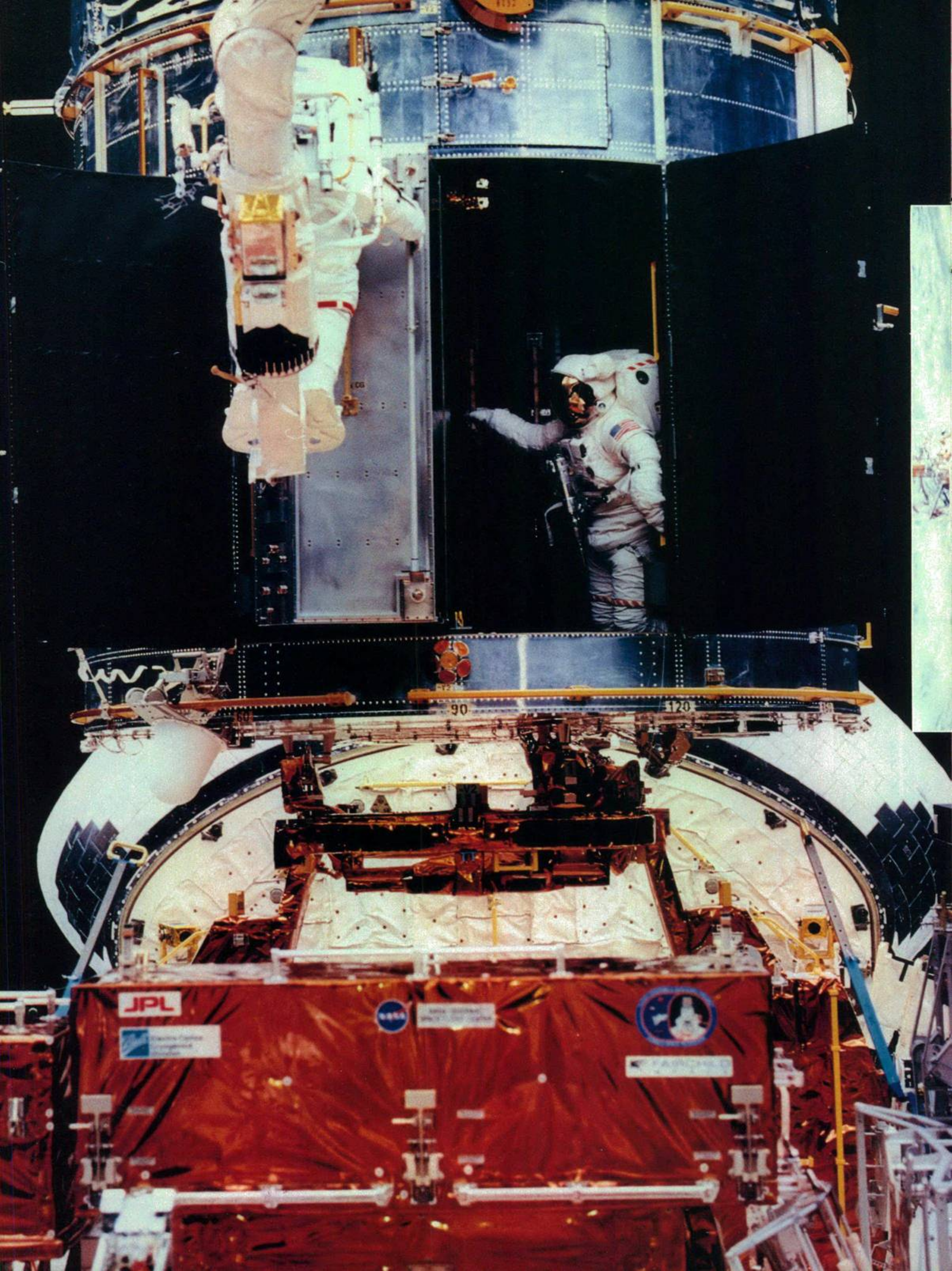
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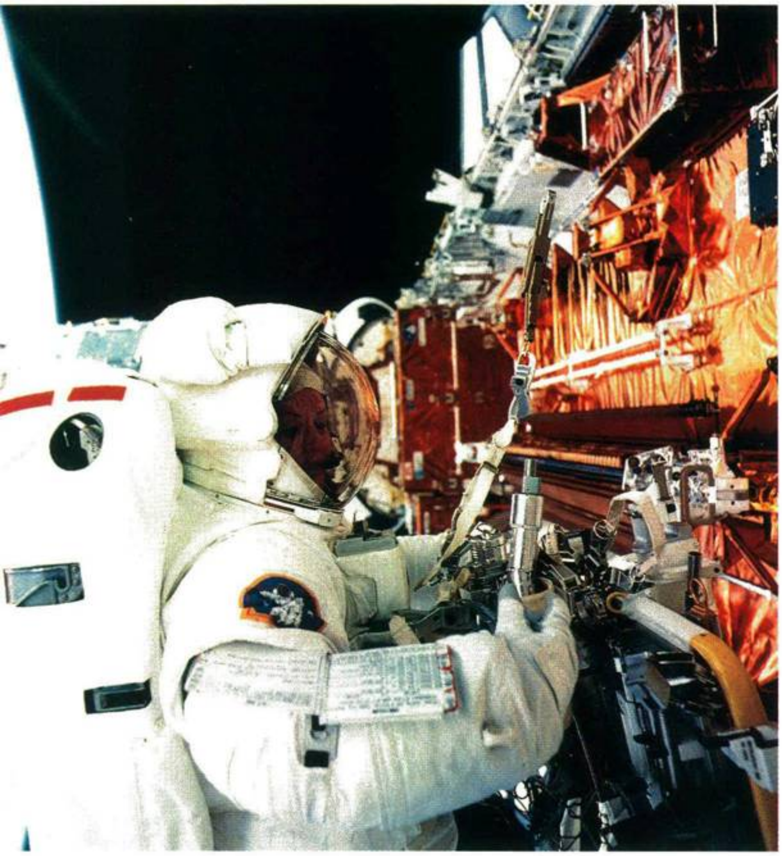
JPL

HELPING HUBBLE SEE BETTER are Tom Akers, seen inside the future home of the corrective optics package, and Kathy Thornton, preparing to install it (left). Thornton checks out some of the servicing equipment during the same spacewalk (below). Sporting new solar arrays, six working gyros, and updated scientific instruments, Hubble takes off to explore the universe (right).



see that one of the troublesome solar arrays had become bowed and twisted. The twin arrays had caused problems since the telescope was deployed back in April 1990. Every time Hubble crossed the line between daylight and darkness — twice in each 90-minute orbit — the arrays would expand or contract in response to the swing in temperature. The resulting jitter tended both to blur the images and to cause the telescope to lose its lock on guide stars.

Eliminating the jitter was one of the prime goals of the servicing mission. But the twisted array created a problem: How could the astronauts roll up the array if the support boom was bent? They couldn't. Instead, during the second spacewalk, astronaut Kathy Thornton tossed the damaged array overboard, starting it on a slow fall into Earth's atmosphere, where it will burn up in a year or so. Then she and her spacewalk partner, Tom Akers, installed new and more-powerful arrays incorporating three major design changes to eliminate the jitter.

Replacing the solar arrays was but one of the many vital repairs the spacewalking astronauts were called upon to perform. On the first walk, Jeff Hoffman and Story Musgrave replaced two of HST's Rate Sensor Units, components that each house two gyroscopes. Hubble has six gyros to help point the telescope, but three had either failed or showed signs of failing and astronomers need three in good working order to be able to aim the telescope. The repairs leave Hubble with six healthy gyros.

Although fixing the arrays and gyros was essential to restoring Hubble's health, it did nothing to help the telescope's blurry vision. That task falls to two new scientific instruments: the Wide Field/Planetary Camera II (WF/PC II) and the Corrective Optics Space Telescope Axial Replacement, or COSTAR. WF/PC II replaces the first Wide Field/Planetary Camera and contains corrective lenses designed to accurately focus the light gathered by the telescope's flawed primary mirror. COSTAR replaces the High Speed Photometer and should correctly focus the light heading to Hubble's three other scientific instruments.

The astronauts also had time to replace some fuses, replace the magnetometers that help orient the telescope in space, install a redundancy kit to fix a power-supply problem on one of the two spectrographs, and reboost Hubble to a higher orbit so it doesn't suffer as much atmospheric drag. The only major glitch in the mission came during the fifth spacewalk, while the astronauts replaced the drive electronics for the solar arrays. The electronics package was not designed for servicing, and the astronauts had trouble handling the small screws with their bulky gloves. When one of the astronauts lost his grip on one of the screws, Nicollier deftly swung the manipulator arm so that Hoffman could grab it.

Of course, all this work will be for naught if Hubble's vision doesn't improve. Although all the electronic signals checked out while Endeavour was still nearby, it will take several weeks to see how well the telescope can focus and a few months before you see the results in the pages of ASTRONOMY.

Perhaps no image has come to represent Endeavour's mission more than the one showing Kathy Thornton pushing the solar array overboard. As mission commander Dick Covey fired the shuttle's thrusters to back away from the array, it twisted in the sudden breeze, for a moment looking like a bird flapping its wings. The array could well have symbolized the legendary phoenix, for much as the mythological bird rose from its ashes, Hubble may rise from the ashes of its less-than-auspicious start. ☐

HYPERGIANTS

They're big. They're bright.
They're tearing themselves apart.
And they don't have long to live.

by
James B. Kaler

TUCKED IN THE NEBULOSITY of the Keyhole Nebula, Eta Carinae is a hypergiant star, perhaps the most massive star known. It's the bright star that appears below center in this picture.

Hypergiants are the most energetic stars in the universe: They radiate a few hundred thousand times more energy than our Sun does. But most textbooks often ignore them or lump them together with their slightly fainter but less rare cousins, the supergiants. Hypergiants are more than astronomical oddities, however. They are teaching us about the aging processes of supermassive stars.

Besides improving our knowledge of how stars age, the study of hypergiants links three seemingly disparate groups of stars — the hot Wolf-Rayet stars, luminous blue variable stars, and cool hypergiants. Some of the differences among these stars result from their diverse masses. Other differences appear because we see stars at various stages in their aging process, or evolution.

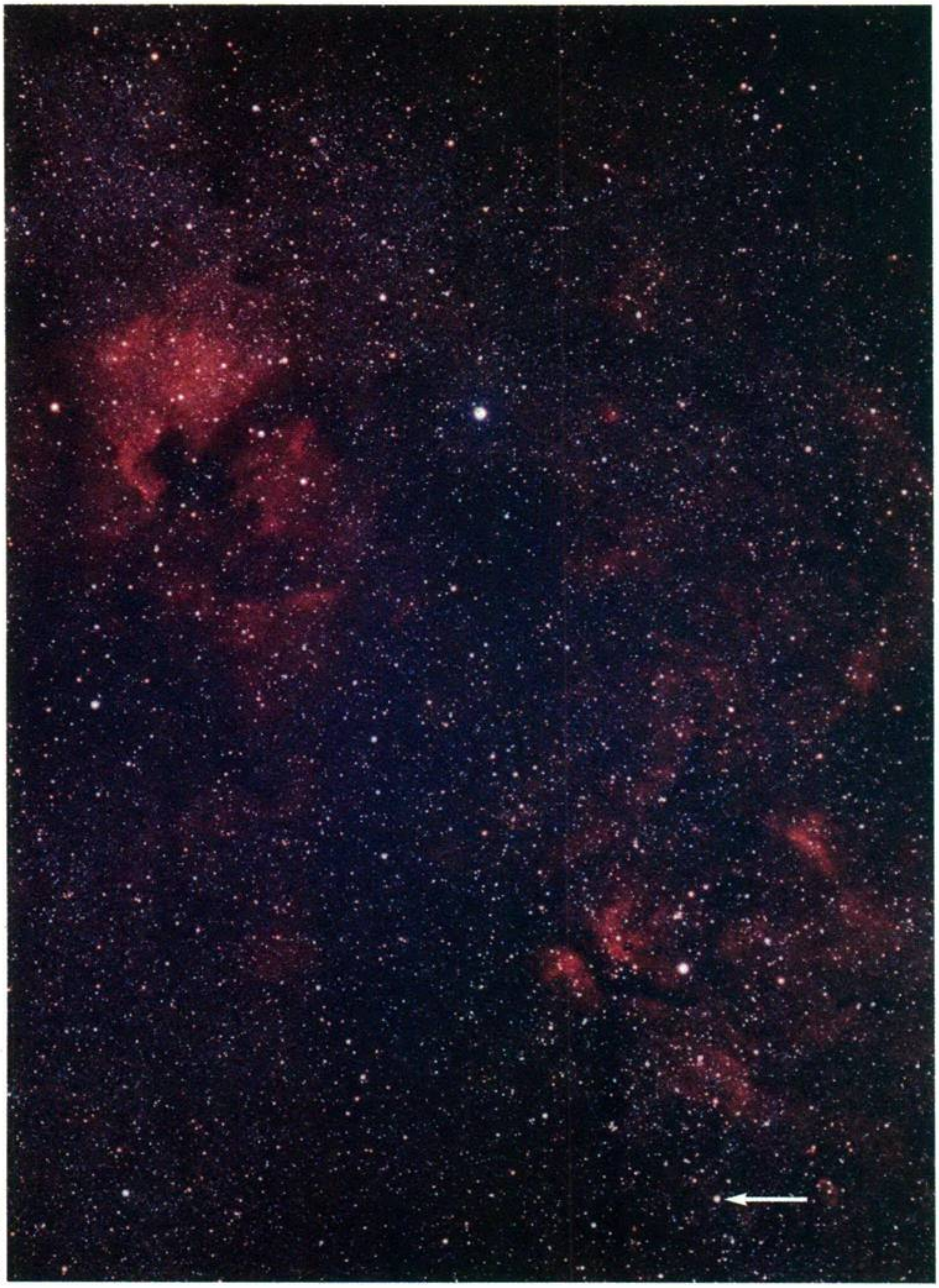
Hypergiants are not very common citizens of our Milky Way Galaxy. Most stars in the Galaxy are small, cool red dwarfs. Less than ten percent are like the Sun, fewer than one in a million is a supergiant, and fewer yet are hypergiants. Because hypergiants look no different than other stars through a telescope, the key to identifying them is to look at their spectra.

Almost all we know about stars comes from their spectra. A star's spectrum displays a rainbow of colors broken by narrow dark lines caused by atoms in the star's atmosphere that absorb light. Each kind of atom produces a characteristic pattern of lines like a fingerprint. Using the strengths of the dark lines created by atoms of hydrogen, helium, and metals such as iron and calcium, astronomers group stars into seven types, O, B, A, F, G, K, and M. This sequence marks the temperatures of stars: Type O stars have temperatures around 40,000 kelvins, G stars like our Sun about 6000 K, and M stars about 3000 K.

But temperature isn't the only characteristic that helps us classify stars: Size is important too. Consider the Sun and Capella, a yellowish double star in the constellation Auriga. Each of Capella's two stars has about the same temperature as the Sun but emits about 60 times more energy than the Sun does. A star's temperature determines only how much energy each square meter on its surface emits, so any difference in luminosity for two equally hot stars must result from a difference in their sizes. The Sun is a dwarf, or main sequence star. The greater luminosity of Capella's twin components means they are about eight times larger than the Sun, making them giant stars.

More luminous than the giants are supergiant stars. These are even larger and can have a diameter about the size of Jupiter's orbit. Betelgeuse in Orion is an example of a supergiant.

To categorize stars of different size and luminosity, researchers added Roman numerals to the spectral types to indicate luminosity classes, referring to main sequence stars as class V, subgiants as IV, giants as III, bright giants as II, and supergiants as class I. (These numbers mimic the magnitude system, with larger numbers referring to fainter stars.) These five classes proved insufficient because astronomers uncovered some stars that were more luminous than the supergiants. So they added a brighter category — the hypergiants. With no



Jack Marling

HYPERGIANT P CYGNI, visible to the unaided eye, lurks just below the bar of the Northern Cross.

Roman numerals below I, they called the very brightest stars class 0.

The luminosity classes are useful for grouping stars, but astronomers prefer to use luminosity measurements when studying individual stars. Just as they use apparent or visual magnitude to report the brightness of a star as seen from Earth, astronomers use absolute magnitude to report the luminosity of a star. For example, the Sun shines brightly with an apparent magnitude of –26.7 because it is so close, but it has an absolute magnitude of only 4.8.

Hypergiants have extraordinary absolute magnitudes. For example, P Cygni shines at absolute magnitude –8.6. The difference of 13.4 magnitudes between the Sun and P Cygni means P Cygni pours out 230,000 times more energy in the visible part of the spectrum than the Sun.

Yet the remarkable visual luminosity of hypergiants tells only part of the story. Hot O and B stars radiate most of their light in the ultraviolet part of the spectrum, so visual magnitudes give a distorted view of these stars' total energy output. Astronomers, therefore, use another kind of magnitude, bolometric magnitude, which measures a star's energy output at all wavelengths. The relation between visual and bolometric magnitude depends upon a star's temperature. For the 6000 K Sun, the difference between the two magnitudes is only 0.08 magnitude; for P Cygni, a B-type star with a temperature near 20,000 K, it's 1.3 magnitudes. P Cygni would appear 3.3 times brighter if your eyes could see the entire spectrum.

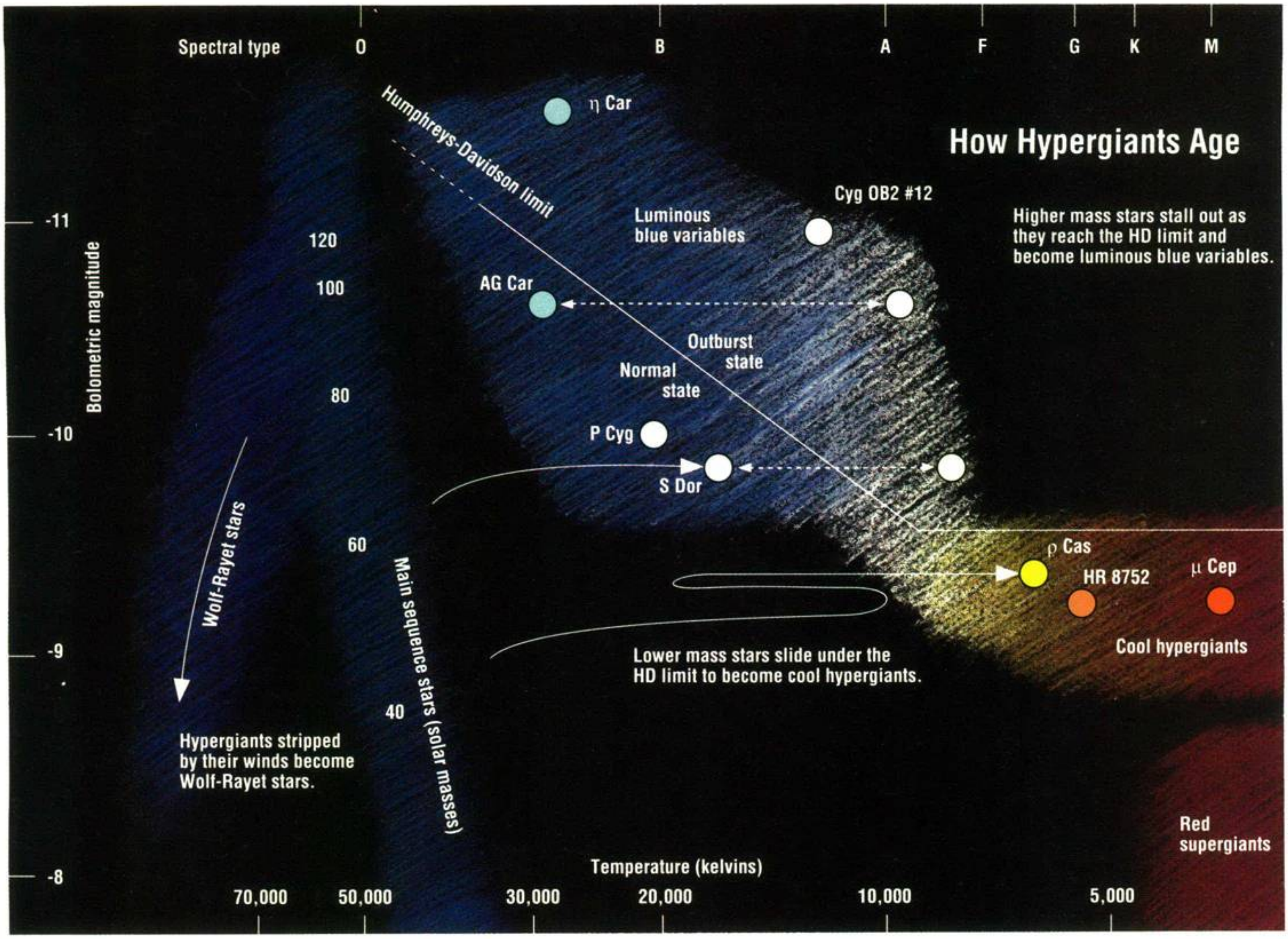
P Cygni lies 7,000 light-years from Earth. But because it is so energetic, we can see it with our unaided eyes. It has an intriguing history of brightness changes. In 1600 the star shone not at 5th magnitude, but at 3rd. By 1630, it had dropped to 6th magnitude, and after some meandering arrived near magnitude 4.8 where it has been for the past 200 years.

Although only a handful of hypergiants exist in our Galaxy and all are far away, they are so bright that you can see several others besides P Cygni with your unaided eye. At the faint end of the hypergiant realm (and usually considered to be a luminous supergiant) is Herschel's "Garnet Star," Mu Cephei. Its low temperature, combined with the scattering of blue light by dust between us and the star, makes its reddish color obvious with binoculars. The star is one of the largest known; were it in the Sun's place, it would extend to roughly the orbit of Saturn.

Two real hypergiants appear near Mu Cephei in western Cassiopeia — Rho Cassiopeiae and HR 8752 (number 8752 in the *Bright Star Catalogue*). These cool hypergiants are brighter and hotter than Mu Cephei and fall into the yellowish white spectral types of F and G. Rho Cassiopeiae, like P Cygni, reveals an essential quality of hypergiants: Their brightness varies over the years. But the two stars behave oppositely. P Cygni goes through occasional outbursts in which it brightens; it was first recorded during such an outburst and long ago faded to "normal." Rho Cassiopeiae, instead of brightening, faded in 1945 from magnitude 4.5 to 6 and became cooler, changing from spectral type F to M. It took two years to return to "normal."

The hypergiant in our Galaxy with the brightest absolute visual magnitude — about –10 — is Cyg OB2 #12 (star number 12 in the second association of O and B stars in Cygnus). But for the champion of hypergiants, we must look to the southern skies and the constellation of Carina.

Eta Carinae, visible from the Southern Hemisphere, resembles a



ASTRONOMY: Phil Kirchmeier

HYPERGIANTS YOU CAN SEE

Star	Spectral type	Magnitude			Distance (l-yr)	Remarks
		Visual	Absolute	Bolometric		
Eta Carinae	B	6.2	−10	−11.5	8,000	luminous blue variable
Cyg OB2 #12	B	11.5	−10	−10.9	5,700	visually brightest star in our Galaxy
AG Carinae*	F	6	−11	−10.7	20,000	luminous blue variable
P Cygni	B	4.8	−8.6	−9.9	7,000	sleeping luminous blue variable
S Doradus*	A	8.6	−9.8	−9.8	170,000	luminous blue variable
Rho Cassiopeiae	F	4.5	−9.6	−9.6	8,000	cool hypergiant
HR 8752	G	5.0	−9.3	−9.5	11,000	cool hypergiant
Mu Cephei	M	4.1	−8.0	−9.2	2,600	very luminous superpergiant

*Figures quoted for maximum light

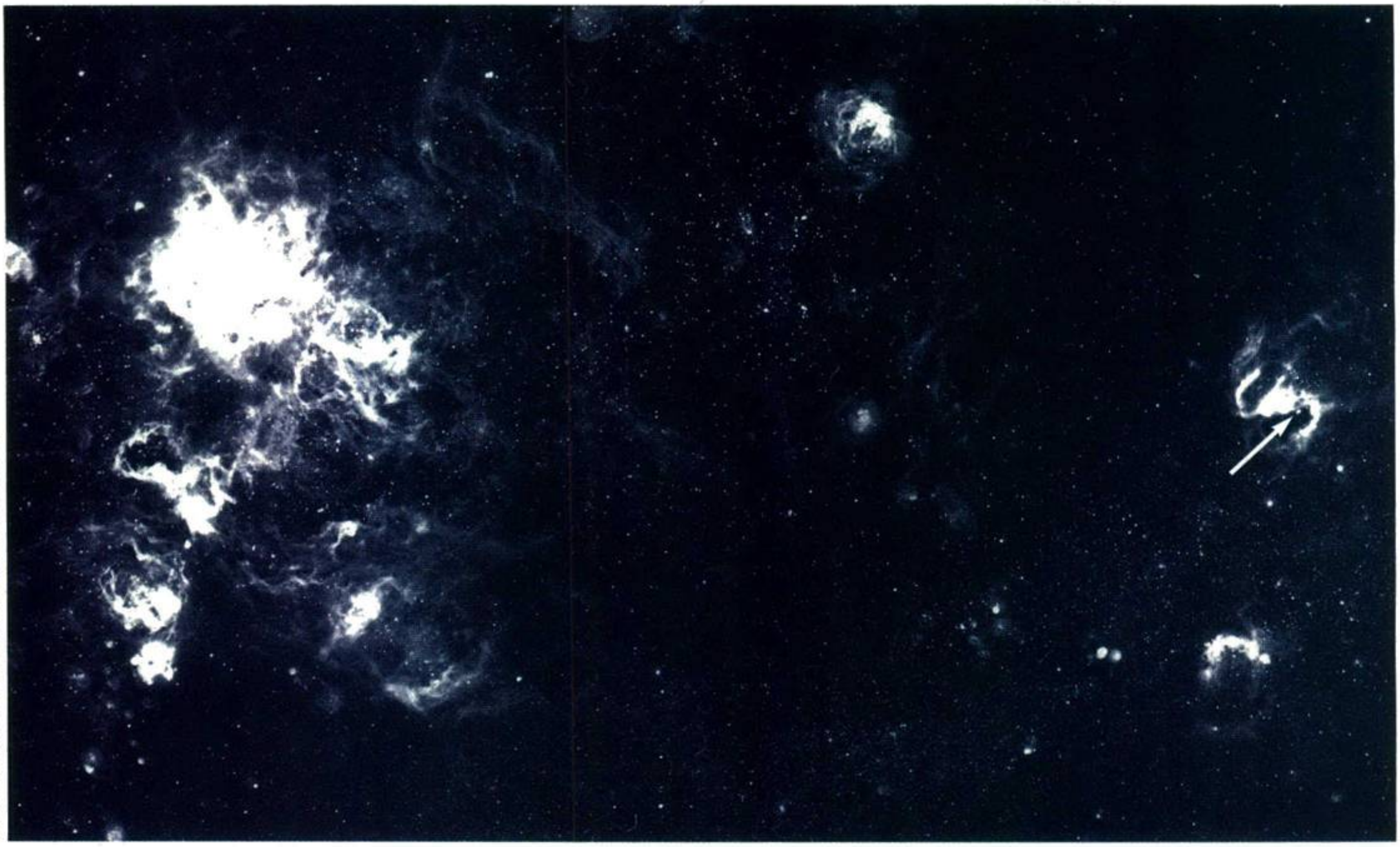
grand version of P Cygni. It shone between 2nd and 4th magnitude during most of the 1700s and early 1800s. Then around 1840 it began to brighten and by 1848 had reached magnitude –1. And then Eta began a great drop and by 1880 had plummeted below naked-eye visibility to 8th magnitude. A spectrum taken in 1893 shows that it had an F supergiant type of spectrum. The star has since climbed to 6th magnitude and the stellar spectrum has disappeared, replaced by the emission spectrum of the surrounding dusty nebula. Only the star's infrared radiation now penetrates the dust.

Recent observations of Eta Carinae show that it is actually a collection of several supermassive stars. Astronomers estimate that the largest of these contains roughly 100 times the mass of the Sun and may be the most massive star in our Galaxy.

Our study of hypergiants isn't limited to just our galactic neighborhood. Hypergiants are so brilliant that we can single them out in other galaxies. In the early 1950s, Edwin Hubble and Allan Sandage discovered several bluish white hypergiants that vary in brightness in the Andromeda Galaxy and a spiral galaxy in Triangulum (M33). Among the brightest stars in the Large Magellanic Cloud lies the brilliant variable hypergiant, S Doradus. Hubble and Sandage suggested that these hypergiants, plus Eta Carinae, are all related. Astronomers now call them luminous blue variables.

The characteristic that links the luminous blue variables together is prodigious mass loss — strong winds blow considerable amounts of the stars' outer layers into space. Indirect evidence for the loss is the thick nebula around Eta Carinae. Direct evidence for mass loss comes from the spectrum of P Cygni, which is unlike that of any other naked-eye star.

Instead of the normal dark absorption lines, P Cygni has bright emission lines flanked on the blueward side by absorption lines. Atoms in the shell of hot gas around the star gener-



Robert Kennicutt, Cerro Tololo InterAmerican Observatory

IN THE HEART of the Large Magellanic Cloud and near the Tarantula Nebula lies the luminous blue variable star, S Doradus.

ated by its wind emit rather than absorb energy to form the bright lines. The part of the shell that appears in front of the star absorbs light from the star and creates the absorption lines. Because the front part of the shell is moving toward us, light emitted by atoms in this region has its wavelength Doppler shifted to the blue. Thus the dark lines from the front part of the shell flank the blue side of the bright lines emitted by the rest of the shell. Whenever astronomers see these highly distinctive "P Cygni lines" in a star's spectrum, they know it has a strong wind blowing gas off the star's surface.

P Cygni's wind, blowing at a few hundred kilometers per second, causes the star to lose mass at a rate of a few hundred-thousandths of a solar mass per year. Though this rate may seem small, it's a billion times greater than what the Sun loses each year. Astronomers believe Eta Carinae at its peak lost a tenth of a solar mass per year for 25 years, throwing an amazing two to three solar masses out into space.

Mass loss is not confined to the luminous-blue-variable class of hypergiants. All hypergiants lose mass. For example, dense shells of dusty molecular gas encase the cool hypergiants.

So hypergiants share two main characteristics: high mass loss and enormous luminosity. Yet at first glance the mixture of cool hypergiants and luminous blue variables appears a jumble. Stellar evolution is the key that makes sense out of this extraordinary zoo of brilliant stars.

The differences among hypergiants result from how stars of different mass age. Stars start their lives on the main sequence. Their masses range from a little less than a tenth to over 100 times the Sun's mass.

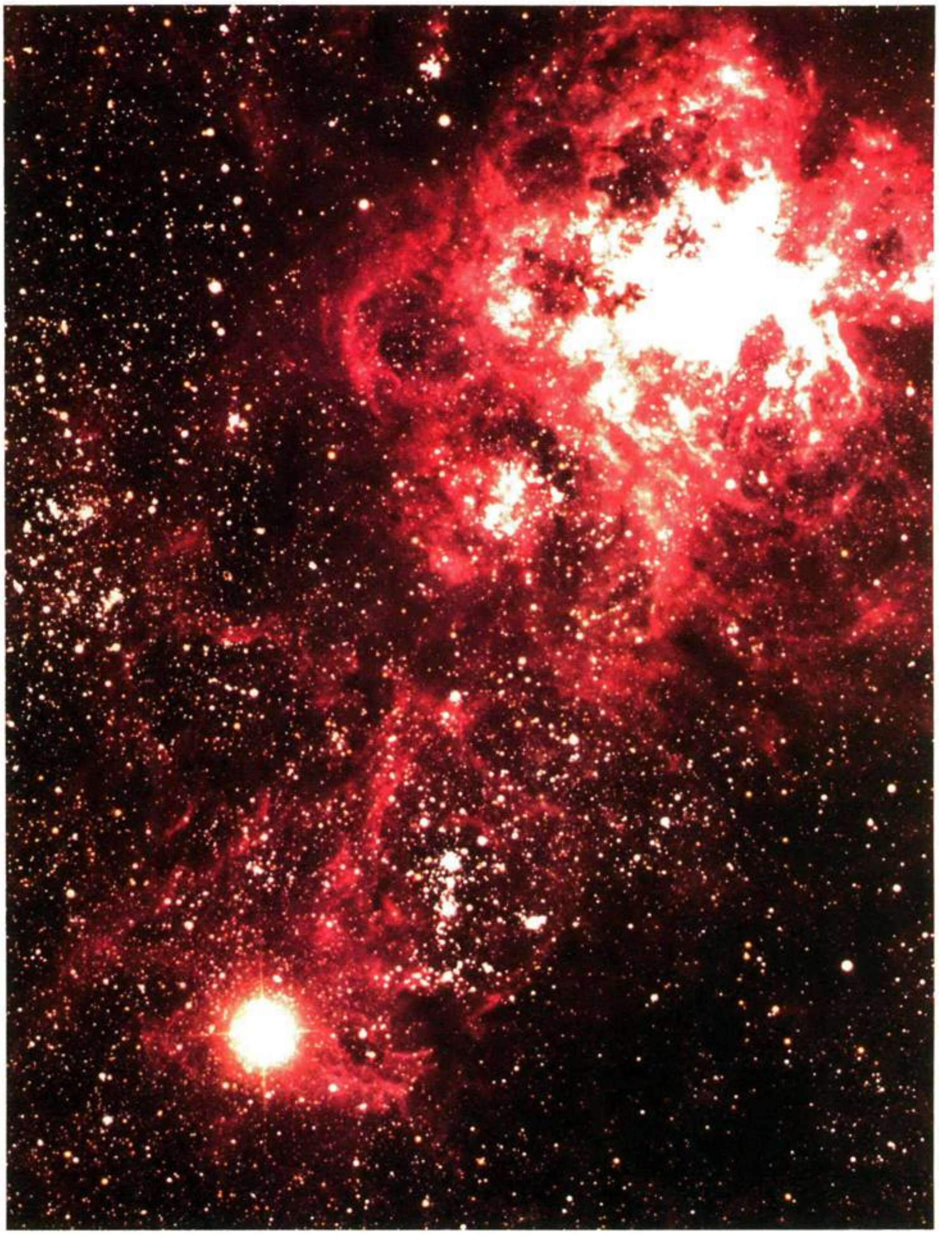
Higher mass leads to greater gravitational squeeze, higher internal temperatures, and, consequently, greater luminosity. But if gravitational energy were the only form of stellar energy production, a star like the Sun would release its gravitational energy and die in a mere hundred million years. Main sequence stars last far longer, over 10 billion years for Sun-like stars, because they fuse hydrogen atoms into helium deep in their cores where the temperature climbs to greater than 10 million kelvins.

When the hydrogen supply in the core of a Sun-like star runs out, the core shrinks under the action of gravity. This gravitational squeeze increases the core's temperature, and the star becomes temporarily brighter. The new energy forces the outer layers of the star to balloon outward and cool, causing the dwarf to become a red giant. High-mass dwarfs (between 10 and 40 solar masses) do not brighten during this stage of their evolution. They instead maintain their luminosity while becoming larger and their surface cools. These stars turn into supergiants.

For awhile, red giants sustain themselves by fusing helium into carbon, and supergiants by further fusion reactions. "Burning" helium provides only a short supply of energy, so the red giant lasts only a brief time. The supergiants, being more luminous, expend their meager remaining sources of energy even more quickly.

Hypergiants develop in essentially the same way as supergiants do, but they push the upper limits of how big and bright a star can become. Normal stars adjust their energy outflow to create a high enough temperature and gas pressure to balance the pull inward from the star's

A HYPERGIANT ENDS ITS LIFE with a bang, similar to the way the blue supergiant Sanduleak –69° 202 became supernova 1987A, the bright star at bottom left.



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gravity. In hypergiants, the outward pressure created by light can be more important than the pressure created by gas. The Eddington limit, named after the British astrophysicist Sir Arthur Eddington, who first noted this theoretical boundary, marks the maximum luminosity a star can achieve before the light pressure overbalances the force of gravity and tears the star apart.

Eddington's limit is a theoretical one, but astronomers have discovered its empirical counterpart. Roberta Humphreys and Kris Davidson of the University of Minnesota discovered that stars above 40 solar masses do not become cool hypergiants. The Humphreys-Davidson (HD) limit forms a line in a plot of stellar spectral type and bolometric magnitude (see page 35).

To see how the HD limit affects the way stars of different masses age, imagine two stars, one with 40 times the Sun's mass and the other with 60 times. They both begin their lives on the main sequence below the HD limit. When they exhaust the energy supply in their cores, they start to expand and cool as they rush to the conclusion of their lives.

At this point the two stars begin to age differently, becoming separate classes of hypergiants. The 40-solar-mass star slides under the HD limit as it evolves and becomes a cool hypergiant. Rho Cassiopeiae and HR 8752 are just such hypergiants.

The 60-solar-mass star can't become a cool hypergiant. Its evolution stalls as it approaches the HD limit. By the time it reaches the HD limit, the star has lost maybe half of its initial mass and has become an unstable luminous blue variable.

Normally the wind of a luminous blue variable will blow off a hundred-thousandth of a solar mass a year. Our old friend P Cygni is just such a star and sits on the stable side of the HD limit. But occasionally a luminous blue variable has an episode when it will suddenly increase the flow of its wind by a factor of 100 or more. In the case of Eta Carinae, the mass loss rate increases by a factor of over 1,000.

The gas blown off by the wind expands and cools, hiding the star. But the star inside keeps radiating energy, mostly in the ultraviolet, at a constant rate (its bolometric magnitude stays constant). The cool gas in the obscuring wind reradiates this ultraviolet energy in the visible. The result is that the star's observed spectral type changes from B to F, and its visual magnitude increases suddenly. Once the star discards enough mass to become stable again, the star's spectrum and brightness return to "normal."

The wind of a supermassive star eventually strips the star's entire outer hydrogen envelope, exposing the inner layers that are rich in the by-products of millions of years of thermonuclear fusion. Astronomers call this remnant a Wolf-Rayet star. These odd bodies still lose mass at vigorous rates and they have spectra that are rich with carbon or nitrogen lines but devoid of hydrogen lines. Don't let the word "remnant" fool you, though: Wolf-Rayet stars still rank among the most luminous stars known. They also mark the coming of the end for the star.

Whether a supermassive main sequence star ages into a cool hypergiant or a luminous blue variable and becomes a stripped Wolf-Rayet star, the final result of hypergiant evolution is almost certainly a supernova explosion. In an instant, the star's core collapses and the resulting surge of energy throws off its outer layers. The crushed core is now possibly a neutron star or even a black hole. What began as one of the biggest and brightest stars in our Galaxy ends as one of the smallest and faintest. ☐

James Kaler, a professor of astronomy at the University of Illinois, has written a series of articles for ASTRONOMY *on the nature of stars.*

Anglo-Australian Telescope Board

Seven Mysteries of Galaxies

What astronomers *don't* know about galaxies provides insights into the universe.

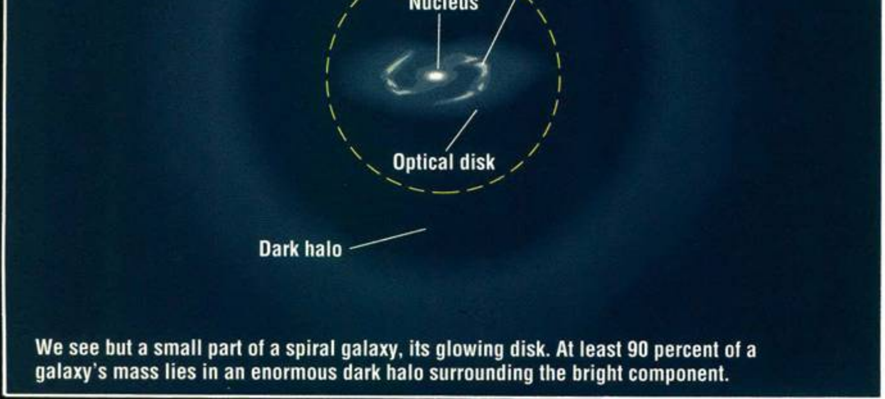
by Jay Gallagher and Jean Keppel

Edwin Hubble discovered the basic nature of galaxies about 70 years ago. Now, in the 1990s, we can still say that we are only on the verge of understanding how galaxies are born, how they work, and what roles they play in the universe at large. Why are galaxies still so stubbornly mysterious?

To be fair, astronomers have made some progress over the past seven decades. We can study at close hand giant spirals like the Andromeda Galaxy and can gain the best view of a galaxy by looking at our own, the Milky Way, from within. It's possible to study large galaxies because they contain vast numbers of stars, on the order of one trillion, with nuclear burning processes that generate visible light. The stars bind together by their mutual gravity and become locked into orbits around the centers of the great galaxies they inhabit.

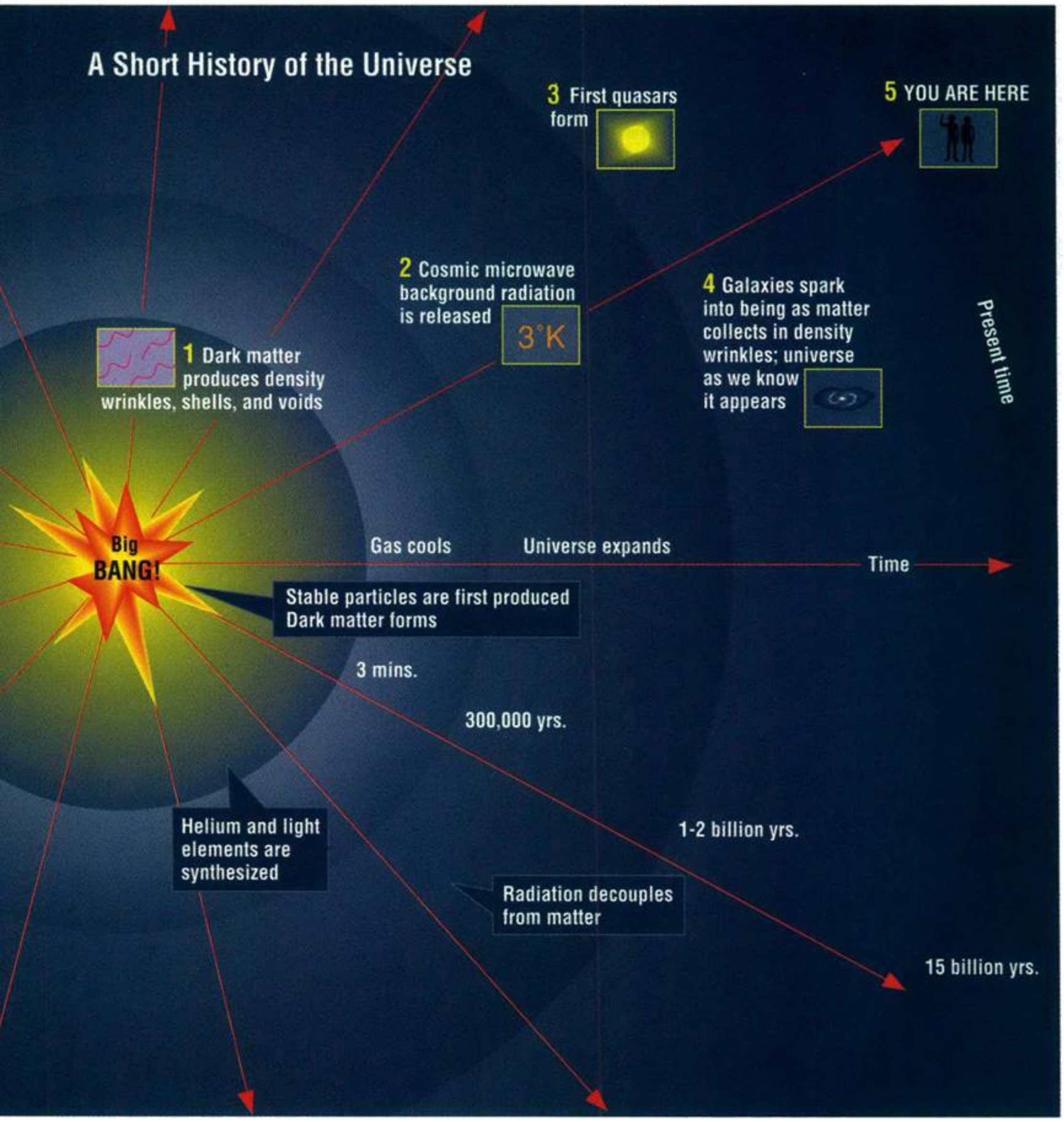
Virtually every star belongs to a galaxy, and so does the majority of gas that forms new stars. Indeed, galaxies are the primary building blocks of the universe. How did this come to be? Let's try to answer this question by highlighting seven mysteries about them. We'll travel back in time to consider how galaxies may have formed. Then we'll jump forward to examine how galaxies are arranged in space. We'll

Spiral Galaxies, 1990s-Style



We see but a small part of a spiral galaxy, its glowing disk. At least 90 percent of a galaxy's mass lies in an enormous dark halo surrounding the bright component.

ASTRONOMY: Phil Kirchmeier, after Jay Gallagher (all diagrams)



A Short History of the Universe

1 Dark matter produces density wrinkles, shells, and voids
2 Cosmic microwave background radiation is released
3°K
3 First quasars form
4 Galaxies spark into being as matter collects in density wrinkles; universe as we know it appears
5 YOU ARE HERE
Present time
Big BANG!
Gas cools
Universe expands
Time
Stable particles are first produced
Dark matter forms
3 mins.
300,000 yrs.
1-2 billion yrs.
15 billion yrs.
Helium and light elements are synthesized
Radiation decouples from matter

also focus on individual galaxies and then work our way into the dense, central hearts of galaxies. At the end of our journey, we'll cast ourselves into the future and ask how galaxies might age. Because these questions reflect the current aims of cutting-edge research on galaxies, this is a story as much about questions as it is about answers.

1 How did the universe change from "wrinkled" to "teeming with galaxies?"

When theoretical cosmologists build a perfect universe, their model probably doesn't contain galaxies. Astronomers know too little about how galaxies formed to include them in such a model. We do know that as the universe cooled after the Big Bang, space became transparent and the light left over from the earliest period after the Big Bang suddenly streamed freely throughout the universe. We see this light today as the 2.73 kelvin cosmic background radiation. This earliest light, dating from 300,000 years after the Big Bang, reveals that the early universe was a soup of atoms —galaxies didn't yet exist.

A few billion years later, quasi-stellar objects, or QSOs, had already formed. We see them today as the earliest signposts of galaxy-sized objects. But what happened in the time between the appearance of the cosmic background radiation and the first quasars? So far astronomers have no observations of this lengthy period. We have no probes of this era during which the universe expanded by a factor of several hundred. Evidently the first large-scale structures condensed in the expanding universe and the first stars were born. But we don't fully understand this crucially important phase of our own universe.

Recent measurements of tiny fluctuations in the cosmic background radiation suggest that slight variations in the density of matter had already appeared by the time the cosmic background radiation was released. Exactly how these fluctuations developed into galaxies is unclear, although it seems that the gravity from luminous matter, the stuff we see as stars and gas, is not sufficient to make these structures collapse. We need something extra to move from the diffuse gas of the Big Bang to a universe of galaxies, and this something could be the unseen material astronomers have dubbed "dark matter."

Our current recipe for making a galaxy goes something like this: Let a Big Bang create the universe and cook it at high temperatures until it produces luminous and dark matter. Use the dark matter to put wrinkles in space with gravity. As the universe expands, the density wrinkles will stand out and collect gas. Cool the gas and wait until it turns into stars. Let the results sit for about 15 billion years and observe them as present-day galaxies. Recognize that there may be many variations on this recipe. For example, we can make giant galaxies either by letting bigger structures fragment or by combining many small pieces into larger objects.

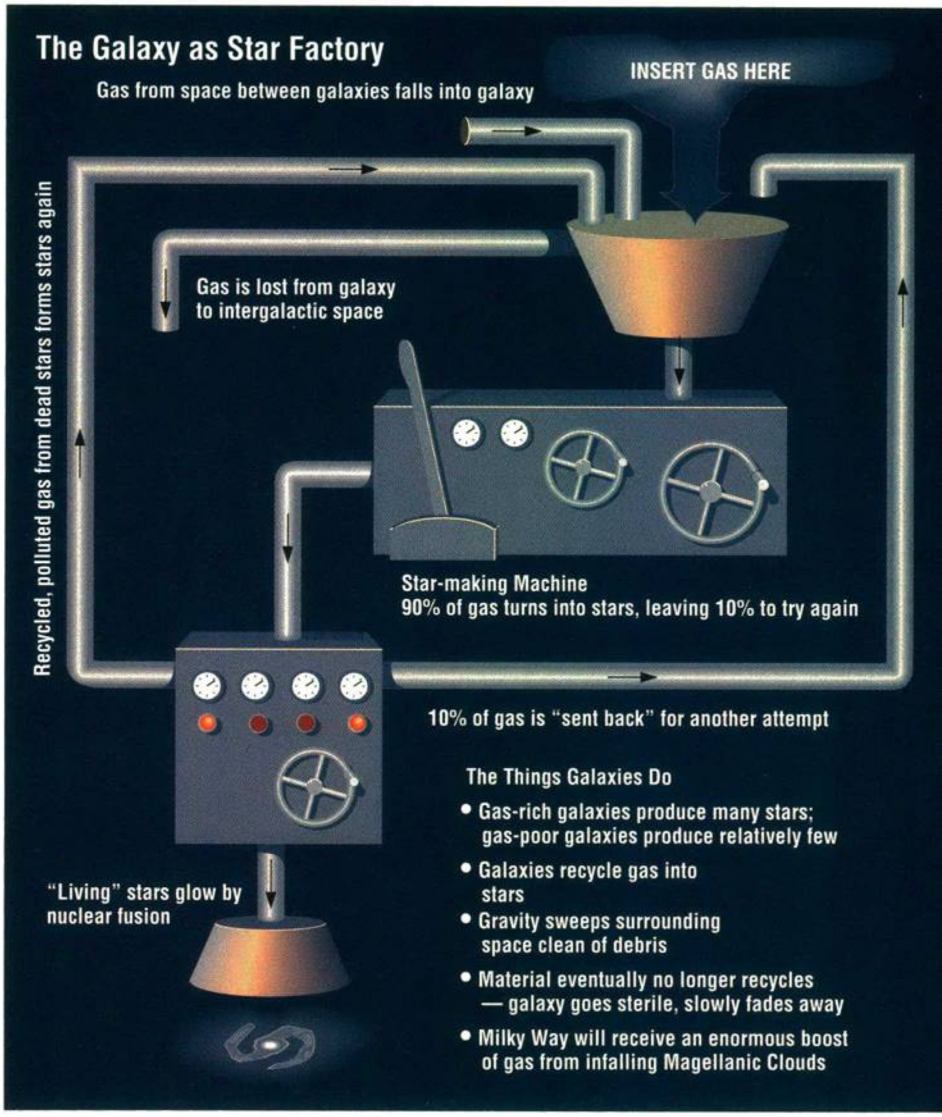
2 Why are galaxies clumped into superclusters?

Galaxies are not just anywhere in space. Any person equipped with a telescope can see this by observing the springtime sky. Bright galaxies cluster in the constellations Virgo and Canes Venatici while other regions of sky like Corona Borealis are much emptier. Deep surveys of galaxies show the real extent of galaxy clustering. They demonstrate that galaxies dwell in sheets and filaments surrounded by vast, empty regions called voids. The galactic sheets and filaments typically measure 100 million light-years across — a thousand times larger than the Milky Way Galaxy.

This arrangement of galaxies in space intrigues astronomers. How did galaxies come to be organized this way? Do the sheets and filaments offer a clue about how galaxies formed, or did the galaxies clump together after they were born? One idea suggests that titanic explosions in the early universe pushed matter into sheets and filaments surrounded by voids. Most astronomers, however, prefer better-known forces such as gravity to create the sheets and voids. Numerical calculations suggest this is possible if nature provided organized, large-scale variations in the density of matter in the early universe. In this model the structure of the sheets and voids is an imprint of the processes rooted in the early universe.

The process by which galaxies clump together poses a significant mystery for astronomers. We want to identify a physical process that makes big sheets and voids, but within the sheets some other process must select just the right sizes and masses to make galaxies. This fascinating problem has initiated a flurry of major programs that have astronomers working toward mapping galaxies out to a distance of one billion light-years.

The Galaxy as Star Factory


INSERT GAS HERE
Gas from space between galaxies falls into galaxy
Gas is lost from galaxy to intergalactic space
Recycled, polluted gas from dead stars forms stars again
Star-making Machine
90% of gas turns into stars, leaving 10% to try again
10% of gas is "sent back" for another attempt
"Living" stars glow by nuclear fusion

The Things Galaxies Do

- Gas-rich galaxies produce many stars; gas-poor galaxies produce relatively few
- Galaxies recycle gas into stars
- Gravity sweeps surrounding space clean of debris
- Material eventually no longer recycles — galaxy goes sterile, slowly fades away
- Milky Way will receive an enormous boost of gas from infalling Magellanic Clouds

3 *Why do the outer parts of galaxies spin so fast?*

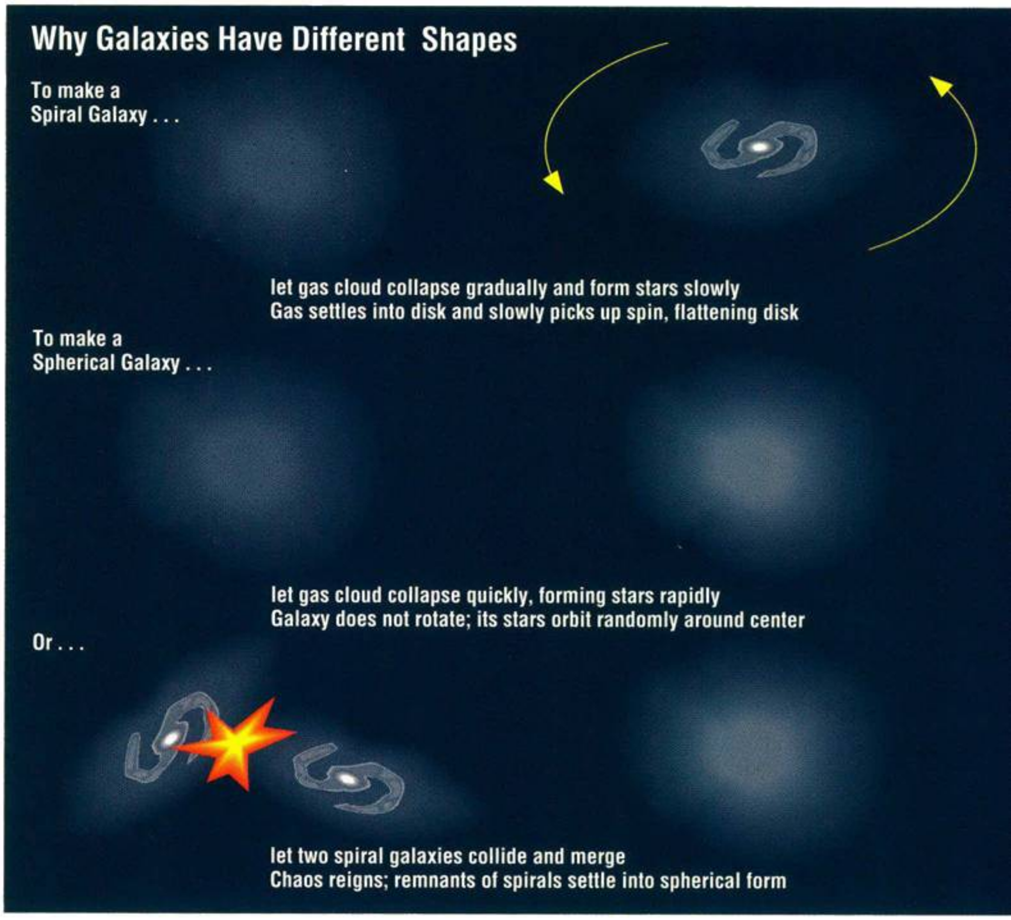
In the mid-1970s astronomers got much better at measuring the rotational velocities of spiral galaxies — the speeds at which their parts rotate around their centers. Much to astronomers' amazement, material in the outer parts of the galaxies rotates at three times the speed astronomers had expected. Before making these measurements astronomers had assumed that all the mass of a galaxy lies in its observed stars and gas. Yet to explain the rapid rotation rates of the outer parts of galaxies, astronomers were forced to assume that vast amounts of unseen mass must surround the visible part of a galaxy. In fact, the flowing stars and gas we see make up only about 10 percent of a galaxy's mass. It's an uncomfortable finding, but alternatives — like the possibility that we fundamentally do not understand the laws of physics — are even less comfortable. So astronomers are focusing on a model of galaxies that says they are much more massive than thought.

This extra mass exists in the form of dark matter. The existence of dark matter surrounding galaxies was actually first suggested in the 1930s by astronomers studying the motions of galaxies near the cores of galaxy clusters. Yet the issue remained an academic footnote for more than 40 years. Now that we see dark matter is the rule rather than the exception, understanding the nature and extent of dark matter is perhaps the most pressing issue facing astrophysics. Astronomers don't like overlooking more than 90 percent of the universe!

The form dark matter takes in galaxies is not known. It could take several forms. High-energy physics suggests the very early universe may have produced exotic elementary particles, heavy relatives of ordinary protons and neutrons. If enough of these survived to the present, they could contribute significant amounts of dark matter. In this view, galaxies are monuments to processes that occurred less than one second after the Big Bang.

Astronomers currently favor the idea that dark matter provided the gravity necessary to make galaxies. The visible parts of galaxies, then, are bright central "islands" embedded in huge dark envelopes. Physicists are now conducting a number of clever searches for dark matter in our own Milky Way Galaxy. These range from looking for massive elementary particles to surveying stars in the Magellanic Clouds to detect light deflected by massive compact halo objects, or MACHOs. These

recently discovered objects may be dwarf stars, Jupiter-sized planets, or brown dwarf stars not massive enough to ignite nuclear reactions in their cores. (See AstroNews, January 1994).


Why Galaxies Have Different Shapes

To make a Spiral Galaxy . . .

let gas cloud collapse gradually and form stars slowly
Gas settles into disk and slowly picks up spin, flattening disk

To make a Spherical Galaxy . . .

let gas cloud collapse quickly, forming stars rapidly
Galaxy does not rotate; its stars orbit randomly around center

Or . . .

let two spiral galaxies collide and merge
Chaos reigns; remnants of spirals settle into spherical form

4 Location, location, location. Is it everything?

Galaxies are sensitive to their surroundings. Within our Local Supercluster, most giant elliptical galaxies lie in regions where many galaxies pack together tightly. (Examples are M87 and M49 in the core of the Virgo Cluster of galaxies.) Spirals, however, abound in less cluttered places. (Examples include M83 in Hydra and M101 in Ursa Major.)

What can we make of this? Are certain types of galaxies created in certain environments? Is there a relationship between the individual galaxy and the structure of the universe on a large scale? That is, does the structure of the universe predetermine how a galaxy will form or the environmental influences that exist around it? Because of this, astronomers have begun to debate the importance of initial conditions versus later processes in shaping the characteristics of galaxies. It's a cosmic version of the "nature vs. nurture" argument.

In the "nature" view, early gravity fluctuations that led to rich clusters of galaxies differed from those that produced sparse regions. Perhaps the ones destined to be clusters offered some special circumstances favorable to forming elliptical galaxies.

In the "nurture" view, the ellipticals may have resulted from interactions with other galaxies, whose dark halos make them gravitationally "sticky." Galaxies born in tight quarters might have been disrupted and merged with other galaxies to form elliptical galaxies. Astronomers who favor this process suggest this or a similar form of nurturing is the main factor in shaping galaxies.

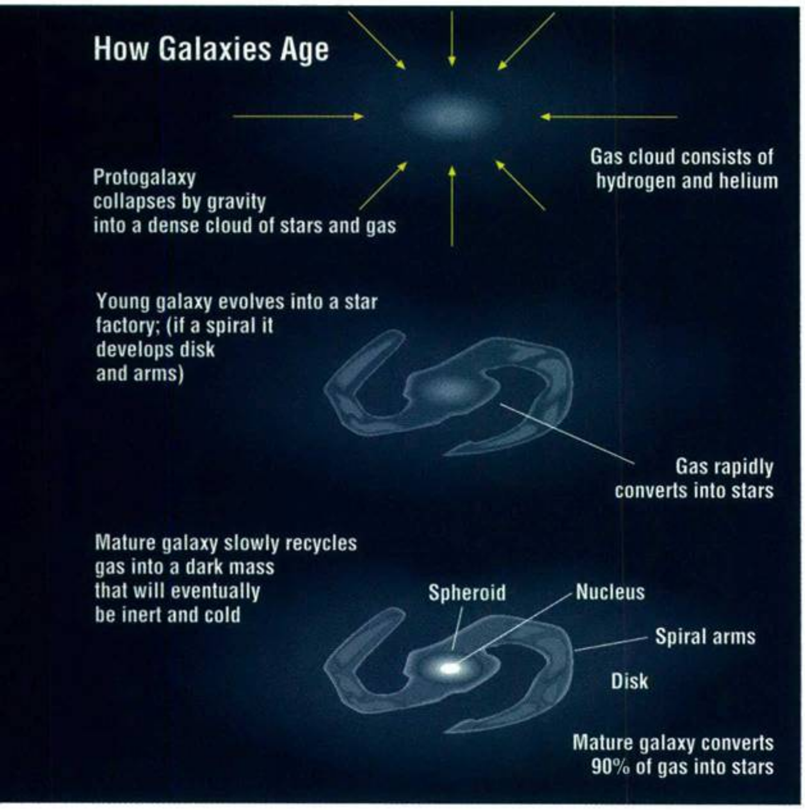
5 Why do different types of galaxies exist?

Two main forms of galaxies exist — spherical balls of stars and spirals. (The much-dimmer dwarf galaxies exist in these forms too.) Astronomers have yet to explain this dichotomy between spherical and spiral structures. They currently believe it may result from the way galaxies form stars as they gravitationally collapse during their earliest days.

To understand the significance of this, remember how galaxies form. The visible parts of galaxies begin their lives as diffuse gas left over from the Big Bang. If the gas collapsed slowly enough and also picked up some spin, it would settle into a rotating disk. This would become a spiral galaxy only if the gas could interact with itself and lose energy. This takes considerable time. If the gas quickly turns into stars that interact with each other only weakly, that is, if stars form before the protogalaxy's collapse is complete, the result is an elliptical galaxy (see above).

Some astronomers prefer a more general version of this picture. Making a spherical galaxy requires some sort of rapid star-forming process such as bursts of star birth that might have occurred in gassy protogalaxies or when two pre-existing spirals merge. Spherical galaxies are anything but perfect spheres, and their apparent similarity hides a wealth of physical differences that offers clues as to how they formed. For example, rotation has flattened the spheroidal bulge of the Milky Way, which you can see on a summer night as the extension of the Milky Way's glowing band into Scorpius. Some flattened elliptical galaxies, however, do not rotate at all. Instead, elliptical galaxies evolve their shapes by the effects of the random, three-dimensional orbits of their stars. Astronomers are not entirely certain how spheroidal galaxies get into such states or whether they will remain stable over cosmic time scales.

While spheroids are dynamically "hot" stellar systems, disk galaxies are dynamically cold, meaning the organized, predictable motions of stars in the disk are more significant than the three-dimensional chaotic motions. Cold structures can experience instabilities as


How Galaxies Age
Gas cloud consists of hydrogen and helium
Protogalaxy collapses by gravity into a dense cloud of stars and gas
Young galaxy evolves into a star factory; (if a spiral it develops disk and arms)
Gas rapidly converts into stars
Mature galaxy slowly recycles gas into a dark mass that will eventually be inert and cold
Spheroid
Nucleus
Spiral arms
Disk
Mature galaxy converts 90% of gas into stars

waves sweep through the disks. Indeed, most spiral disks appear to be on the edge of stability and are therefore rich in features like spiral arms or bars. These arms or bars collect lots of gas in galactic disks, which in turn yield lots of stars, including bright massive ones. This explains why the spiral arms of galaxies like the Whirlpool in Canes Venatici stand out so clearly.

6 Do "Monsters" Lurk in the Centers of Galaxies?

The centers of many galaxies contain ultrarich clusters of stars. (Some appear to contain much more exotic features like massive black holes.) The cores of galaxies are small, about one light-year across, but the densities of stars they contain can be incredible. For example, the nucleus of the Andromeda Galaxy appears as a central "star" in the diffuse glow of the galaxy's central bulge. It has a density of stars one million times higher than that in the Sun's neighborhood. If the dust that blocks our view of the Milky Way's nucleus were somehow removed, our Galaxy's nucleus would appear in the sky as a slightly fuzzy, 0-magnitude star. Astronomers on a planet near the galactic center would have a sky full of stars and would be able to see other galaxies only with difficulty.

Why such dense objects form in the centers of galaxies isn't entirely clear, although their unique location no doubt is crucial. As gas and stars in a galaxy brush and collide, they sink more deeply toward the galaxy's center. But nothing can sink past the center of a galaxy, and it's likely that considerable amounts of matter could collect and merge into a nucleus.

While many galaxies form dense nuclei from stars that migrate inward, not all galactic nuclei form that way. Luminous nearby galaxies like M77 in Cetus and NGC 4151 in Canes Venatici contain powerful nuclear sources of high-energy particles that dwarf the centers of normal galaxies in energy output. Quasars are far more powerful still, containing centers the size of normal galactic nuclei that release 100 times the energy of all the trillion stars in an entire normal galaxy.

Astronomers are only beginning to understand the details of how these active galaxies and quasars work. Most astronomers think the centers of these galaxies contain a massive black hole, perhaps evolved from dense stars that collided, and a source of ordinary material that falls into the black hole and emits powerful bursts of energy.

Proving the existence of black holes continues to be one of the hot areas of astronomical research. Astronomers search for black holes in the centers of nearby galaxies, chiefly with the resolving power of the Hubble Space Telescope. Even if Hubble unambiguously detects the signature of a black hole in a nearby galaxy, astronomers will have plenty of work ahead to understand how they form and behave.

7 What will happen to the Milky Way?

Galaxies change. The Milky Way recycles gas into stars and back again. Because some matter ends up locked away in stellar cinders like white dwarfs and neutron stars, the recycling isn't perfect. Eventually the Milky Way's supply of interstellar gas will be exhausted. In that bleak period of the Galaxy, new stars will no longer form and the Milky Way will become a sterile system with a retinue of slowly dying stars. Our Galaxy will gradually decline in brightness over tens of billions of years as its stars grow old. Astronomers have catalogued other galaxies that are already stellar fossils. Examples include gas-free elliptical galaxies like M84 in Virgo and M105 in Leo. Without fuel to feed their growing black holes, active galaxies will decrease in power. Are galaxies fated to gently disappear from view as they exhaust their internal supplies of gas?

Fortunately, internal processes are not the only factors that influence how galaxies evolve. Galaxies can

Canada France Hqawaii Telescope

change drastically by interacting with other galaxies or the gas that surrounds them. Many dwarf galaxies contain untapped reservoirs of gas that can re-energize active galaxies or support the births of new stars if the dwarfs fall into larger galaxies. In our future, the Magellanic Clouds will refuel the Milky Way in this way and extend the Milky Way's life as a vital galaxy by many billions of years. The Clouds will fall into the Milky Way several billion years from now, be cannibalized by it, and add their stores of gas and stars to extend our future. We can all sleep better at night knowing that we do not live in the era of our Galaxy's decline!

Understanding how galaxies work is a grand challenge for astronomers of the coming decades. Thankfully, we already have the advantage of seeing snapshots of the life histories of galaxies. Light from distant galaxies has traveled for billions of years and thus offers us the chance to look into the past and directly test our ideas through observations. We already know that long ago quasars and active galaxies were far more abundant than they are now. The challenge for astronomers is to decode the messages they receive from earlier times. With new tools and better ideas, we can anticipate discovering new mysteries about galaxies that will lead us deeper into the universe. □

Jay Gallagher is an astronomer at the University of Wisconsin in Madison and former director of Lowell Observatory. Jean Keppel is an astronomer at Yavapai College in Prescott, Arizona.

SKY ALMANAC

March 1994

The Moon Glides Past Uranus and Neptune

Early risers on March mornings will be greeted by Sagittarius, a prominent constellation that heralds the return of summer stars. On the morning of March 7 the Moon passes close to Uranus and Neptune, both bright "stars" in binoculars but disks viewed under the magnification of a telescope. The three objects form a pretty group on this morning.

A Close Meeting of Saturn and Mercury

As dawn washes over the night on the morning of March 24, bright planets Saturn and Mercury pop over the horizon separated by one-third of a degree. You may catch the planets with an extremely clear and low eastern horizon. Once located, the objects may remain visible in a telescope for several minutes.

Two Periodic Comets Visible

Virgo's smattering of bright stars this month hides an 11th-magnitude periodic comet called Tempel 1. Slowly brightening as summer approaches, Tempel 1 is now visible in backyard telescopes or small binoculars. A fainter comet, West-Kohoutek-Ikemura, glows dimly at magnitude 13 and is currently visible in eastern Perseus.

Morning Pairing of Moon and Spica

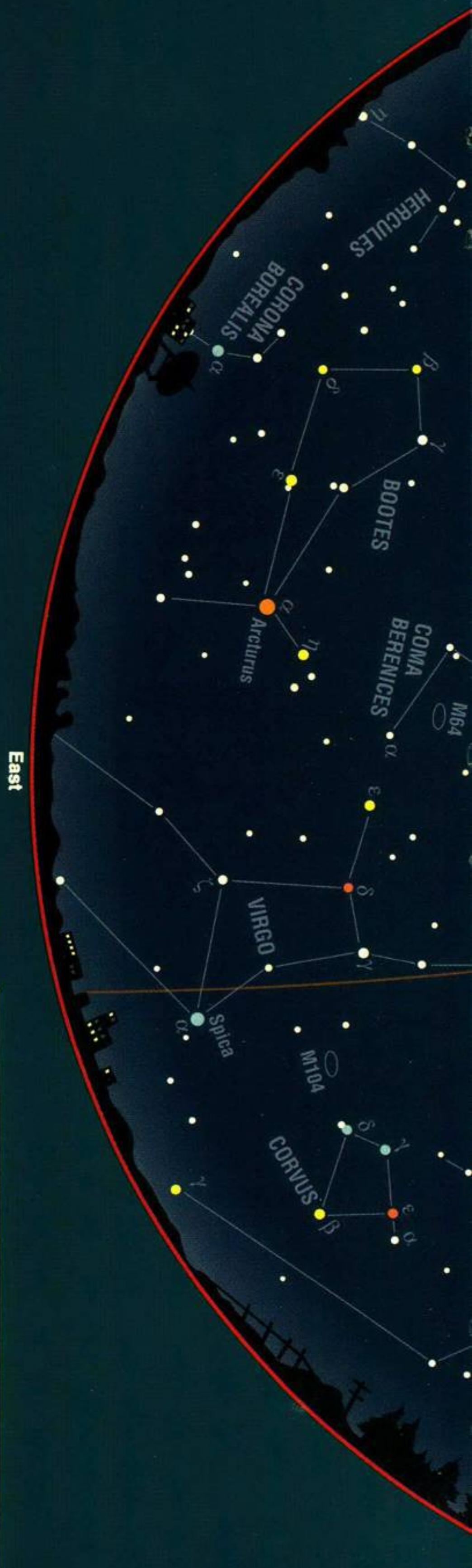
On March 28 look for a conjunction between the Moon and Spica in the early morning sky, just before dawn. Face southwest and you'll see these two, along with the surrounding stars of Virgo.

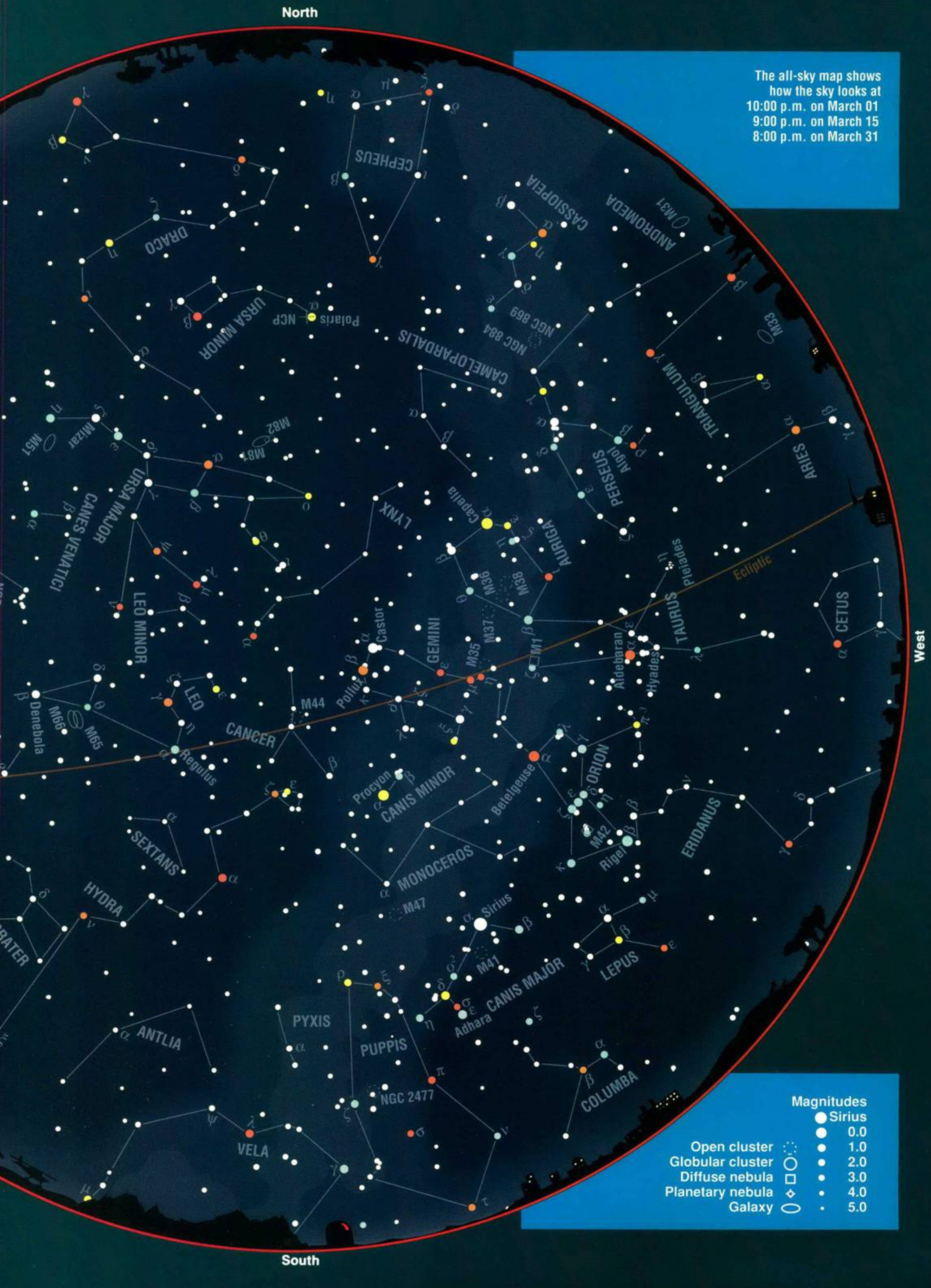
Observe Comet SL-9

Comet Shoemaker-Levy 9 continues its pacing alongside Jupiter. In mid-July the comet will collide with the giant planet in the first event of its kind ever observed. The comet now glows at magnitude 14, requiring a very large telescope or CCD if it is to be seen or imaged.

CALENDAR OF EVENTS

2	The Moon passes 2° south of Jupiter, 11 a.m. EST
3	Pluto is stationary, 8 p.m. EST
4	Mercury is stationary, 7 a.m. EST Last Quarter Moon is at 11:53 p.m. EST
7	The Moon passes 4° north of Neptune, 11 a.m. EST The Moon passes 5° north of Uranus, 4 p.m. EST
12	New Moon is at 2:05 a.m. EST
13	The Moon passes 5° north of Venus, 12 noon
14	Mars passes 0.4° north of Saturn, 5 a.m. EST
15	The Moon is at apogee (252,208 miles from Earth), 12 noon EST
18	Mercury reaches greatest western elongation from the Sun (28°), 9 p.m. EST
20	First Quarter Moon is at 7:14 a.m. EST Vernal equinox is at 3:28 p.m. EST
24	Mercury passes 0.3° south of Saturn, 3 a.m. EST
27	Full Moon is at 6:09 a.m. EST
28	The Moon is at perigee (222,423 miles from Earth), 1 a.m. EST
29	The Moon passes 2° south of Jupiter, 5 p.m. EST





The all-sky map shows
how the sky looks at
10:00 p.m. on March 01
9:00 p.m. on March 15
8:00 p.m. on March 31

North
South
West
CEPHEUS
CASSIOPEIA
ANDROMEDA
M31
DRACO
URSA MINOR
Polaris
NCP
NGC 869
NGC 884
CAMELOPARDALIS
M33
TRIANGULUM
ARIES
PERSEUS
Algol
M81
M82
M51
Mizar
URSA MAJOR
CANES VENATICI
LYNX
Capella
AURIGA
M36
M38
M37
M1
Pleiades
Ecliptic
TAURUS
Aldebaran
Hyades
CETUS
LEO MINOR
GEMINI
Castor
Pollux
M35
M44
CANCER
LEO
Denebola
M66
M65
Regulus
Betelgeuse
ORION
M42
Rigel
ERIDANUS
Procyon
CANIS MINOR
MONOCEROS
SEXTANS
HYDRA
CRATER
M47
Sirius
M41
LEPUS
CANIS MAJOR
Adhara
PYXIS
PUPPIS
ANTLIA
COLUMBA
NGC 2477
VELA
Magnitudes
Sirius
0.0
1.0
2.0
3.0
4.0
5.0
Open cluster
Globular cluster
Diffuse nebula
Planetary nebula
Galaxy

SKY ALMANAC

by Deborah Byrd and Jeff Kanipe

As trees bud and spring flowers bloom in the southern states, the brightest planet, Venus, returns to the evening sky. In early March this planet sets in the west less than an hour after the Sun. It isn't high in the sky, but it's so bright that you can see it easily if you look toward an unobstructed western horizon.

Venus moves a little faster than we do in its orbit, about 22 miles per second in contrast to our 18. In January Venus was behind the Sun, but now it has pulled far enough away from our line of sight to the Sun to become visible again.

There's another reason to look for Venus in the evening sky this month. In the evening at this time of year, the ecliptic, or path of the Sun, Moon, and planets across our sky, stands at nearly right angles to the horizon. So Venus' motion carries it nearly straight up from the horizon, making the planet easier to see than it would be otherwise.

The steep angle of the ecliptic also makes this month ideal for spotting a young Moon. The Moon becomes New on the morning of March 12. That evening it is about 16 hours old as seen from the East Coast after sunset. Seeing a Moon that young is extremely difficult. By the time the Sun sets for West Coast observers, the Moon will be about 19 hours old. West Coast observers who have a clear sky all the way to the western horizon might glimpse the young Moon. The Moon will then be 8° to the lower right of Venus. Use binoculars to look for it no later than half an hour after sunset and then try to see it with the eye alone.

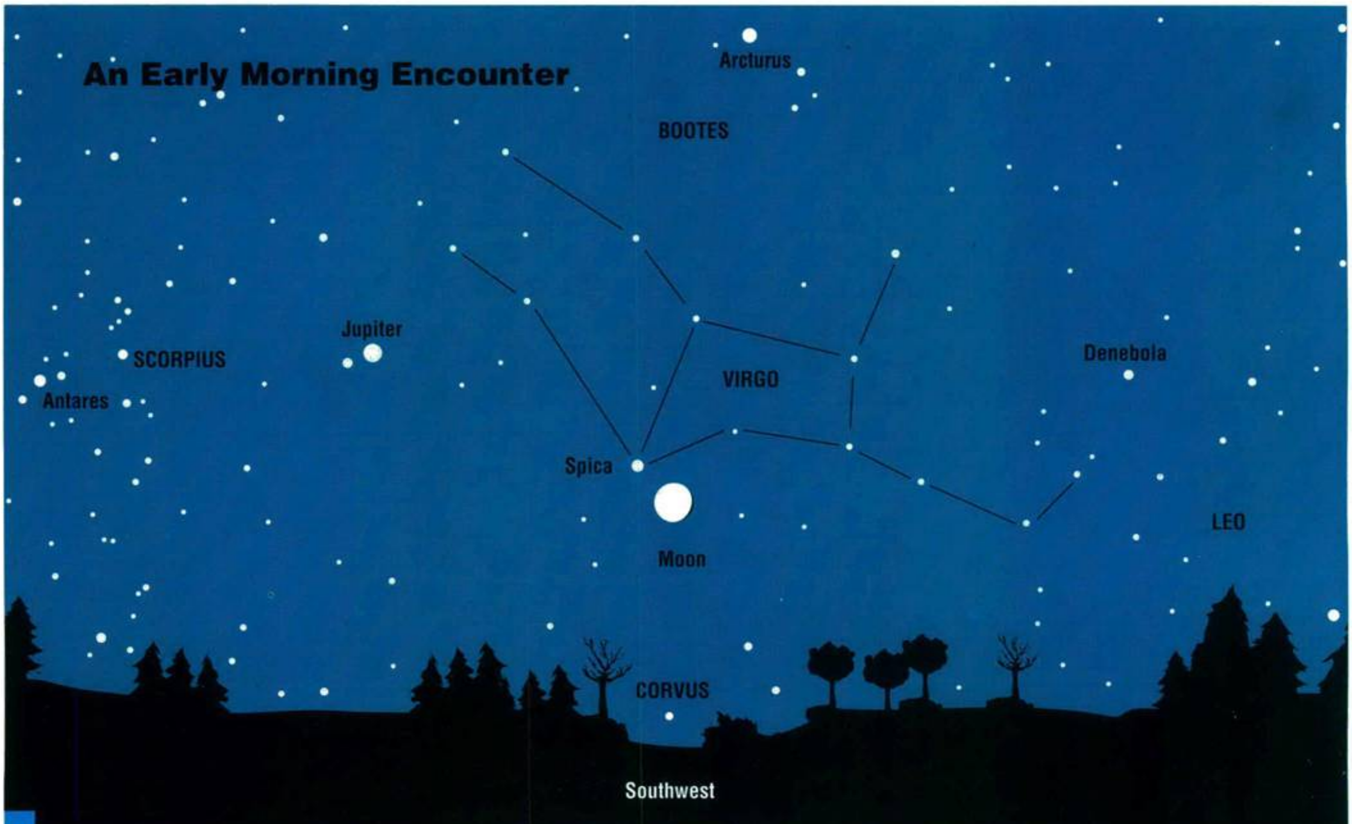
No other planets will be visible until Jupiter, in the constellation Libra, rises late at night. Early in the month, Jupiter rises around 11 p.m. and by month's end rises a couple of hours earlier. You can't miss Jupiter because, with Venus out of the way, only the Moon outshines it in the night sky.

Jupiter shines at magnitude –2.3 this month, and it will grow brighter still before reaching opposition in late April. The bright star right next to Jupiter is Alpha Librae, also known as Zubenelgenubi. As you gaze at Jupiter, you can almost visualize Comet Shoemaker-Levy 9 bearing down on it. At magnitude 14, the comet is too faint to see except in the largest backyard telescopes. It will move along with Jupiter until impacting the planet in late July.

This month Jupiter and a nearby bright star, Spica, offer a way to help you visualize the Moon's eastward motion in orbit around Earth.

Throughout the night of March 27, the Full Moon approaches Spica. On the evening of March 28 the Moon has moved far enough eastward to be located between Spica and Jupiter. By the morning of March 29, the Moon is closing in on Jupiter. That evening the Moon moves past the planet, and you can watch throughout the night as the orbital motion of the Moon carries it ever

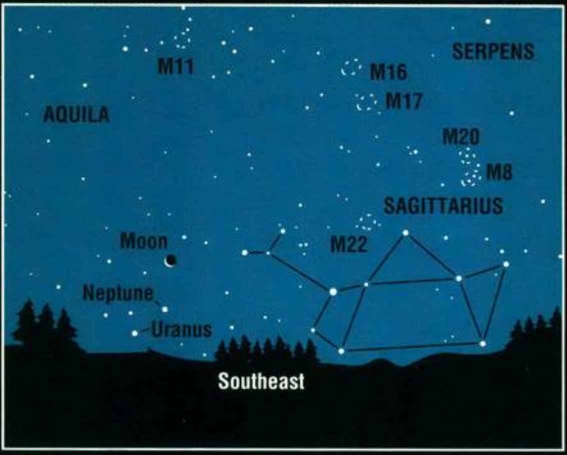
(continued on page 55)

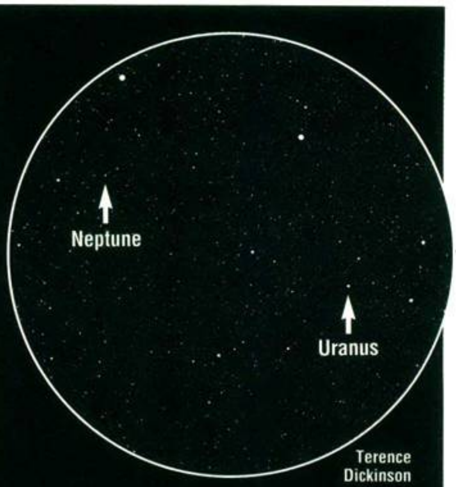


An Early Morning Encounter

Early risers on the morning of March 28 will see a splendid view of the waning gibbous Moon as it edges toward Virgo's brightest stellar beacon, Spica, in the southwestern sky. The separation is about 4° in the early morning hours but closes to about 2.5° as the first blush of dawn colors the eastern sky. Although the Moon is much brighter than Spica, the pairing should make a nice scene in binoculars or a small telescope at low magnification. Also, check out the Moon at higher magnifications while you're in the area. While you're looking at the conjunction, gaze about a degree or so off the dark northern limb of the Moon to see a pretty string of 5th-, 6th-, and 7th-magnitude stars. The two nearest the Moon are 49 and 50 Virginis.

The Moon and Two Giants





Terence Dickinson

Hanging low in the southeast an hour or so before sunrise, the familiar Teapot asterism of Sagittarius foreshadows the bright stars of summer that will grace the evening sky later this year. You don't have to wait until then to observe this rich part of the sky. The distant gas giant planets Uranus and Neptune now hide among the stars east of the Teapot's handle. On the morning of March 7 a waning crescent Moon passes just northwest of the pair, providing an obvious marker to help you find these remote planets.

Because Uranus is brighter than Neptune you may wish to find it first. Use a low-power eyepiece, one with about a 1° field of view, and center the Moon. Then simply reposition your field of view about 5° due south. The sky in Sagittarius appears to be dusted with countless stars, but most are fainter than Uranus' magnitude of 5.8, and none displays a greenish disk like that of the planet. If you're still in doubt about which point of light is Uranus, boost your magnification a little and look for the bloated green "star."

Now shift your field of view 2.2° northwest of Uranus to find Neptune. Increase your magnification to 120x or so and look for an 8th-magnitude dot of light. Large telescopes may reveal the planet's aquamarine color, but you'll still have to look closely to discern this planetary body from the myriad of stars of similar brightness.

Comet Tempel 1 Returns

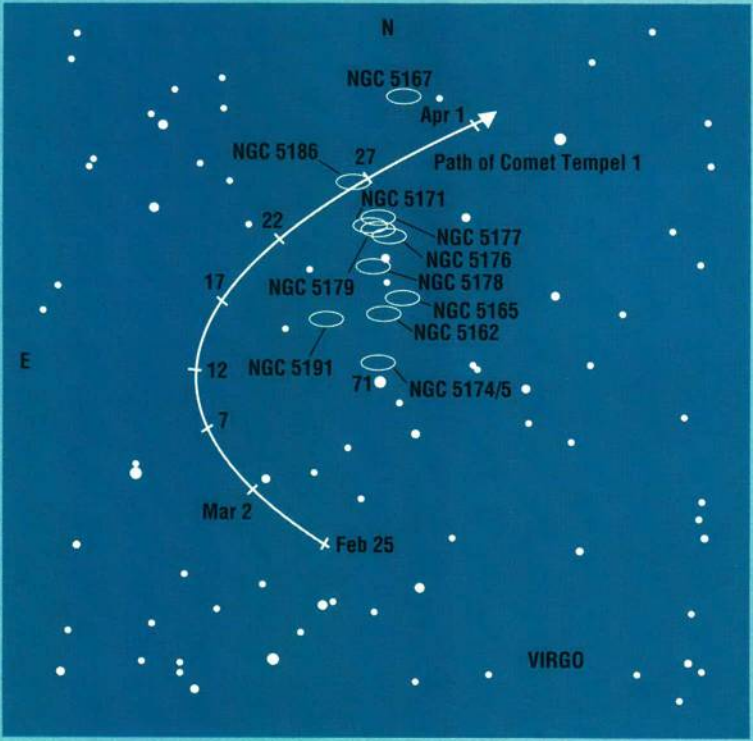
Comet Tempel 1 is currently a slate gray, 11th-magnitude smudge in Virgo. But this month offers a good chance to begin tracking this periodic comet, which promises to brighten considerably by early summer.

Tempel 1 returns to the inner solar system every five-and-a-half years. Though it is classified as a periodic comet and is considered dependable in brightness and orbit, Tempel 1 has sometimes behaved fitfully in the past. The cause is Jupiter's gravitational influence. A close approach to Jupiter in 1881 increased both the comet's period and moved its closest approach to the Sun farther away. This makes Tempel 1 appear faint even when favorably placed. Close approaches to Jupiter in 1941 and again in 1953, however, decreased the comet's period and brought it a bit nearer again.

Currently, Tempel 1 is poised between the feet of Bootes and what I call the "cup of Virgo," an asterism made up of Epsilon (ε), Delta (δ), Gamma (γ), Eta (η), Nu (ν), Pi (π), and Omicron (o) Virginis. A number of bright galaxies lie in this region, but don't let them fool you. See the finder chart to differentiate the positions of the galaxies from the path of the comet.

On March 1, Tempel 1 lies about 7½° southeast of Epsilon Virginis. For the next month or so, this star will be your guidepost in finding the comet. No other bright star marks the region, save for Eta Bootis, and it is fully 9° northeast.

Around mid-month, Tempel 1 hooks sharply northwestward toward Alpha (α) Comae Berenices. And by month's end it lies 6° northeast of Epsilon Virginis and glows at magnitude 10.5.



COMET TEMPEL 1

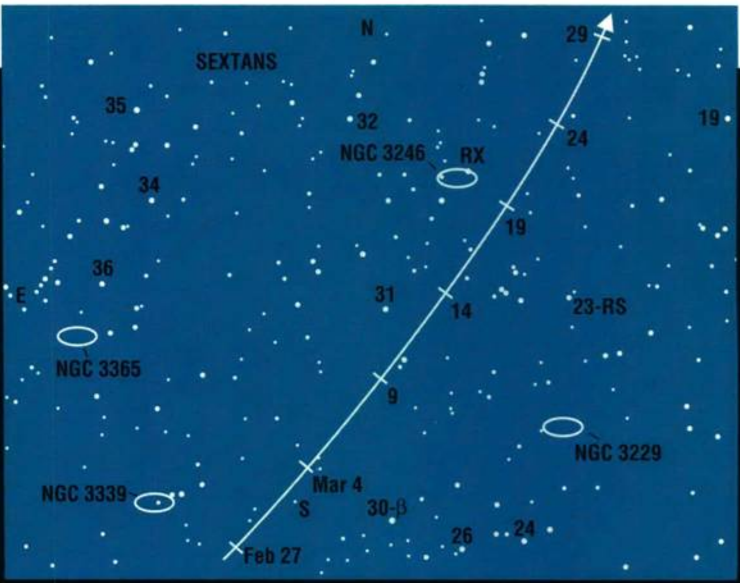
Date	R.A. (2000)	Dec.
Feb. 25	13h30.8m	9°44'
Mar. 2	13h32.6m	10°06'
Mar. 7	13h33.7m	10°31'
Mar. 12	13h34.0m	10°58'
Mar. 17	13h33.4m	11°24'
Mar. 22	13h32.0m	11°50'
Mar. 27	13h29.8m	12°13'
Apr. 1	13h26.9m	12°31'

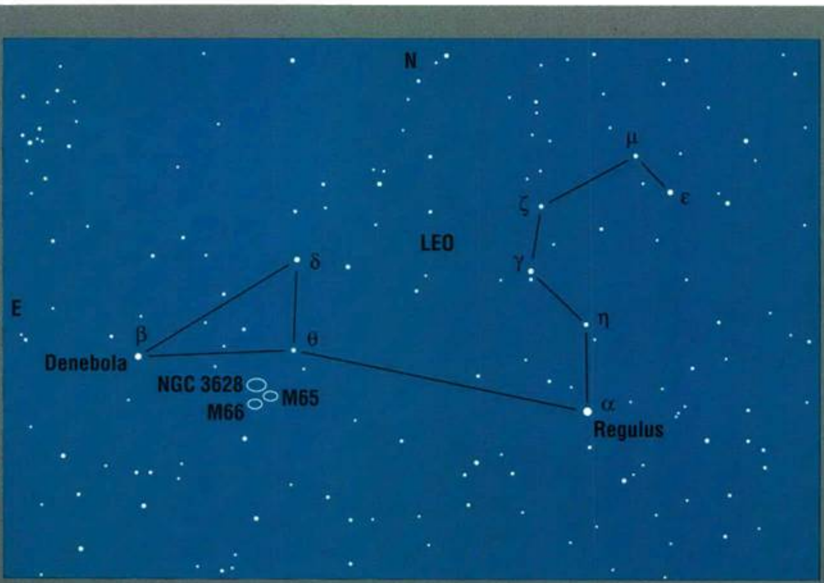
ASTEROID 41 DAPHNE

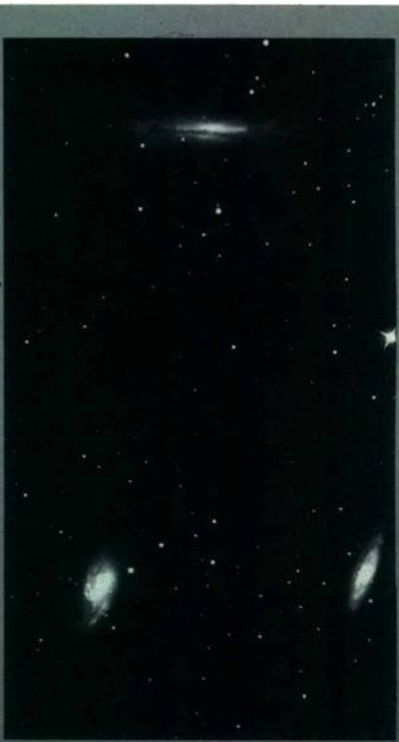
Date	R.A. (2000)	Dec.
Feb. 27	10h38.2m	–1°00'
Mar. 4	10h34.5m	0°04'
Mar. 9	10h30.8m	1°12'
Mar. 14	10h27.4m	2°21'
Mar. 19	10h24.3m	3°30'
Mar. 24	10h21.7m	4°38'
Mar. 29	10h19.7m	5°42'

Tracking Asteroid 41 Daphne

This month is a good time to follow 41 Daphne, now moving through Sextans, a faint kite-shaped constellation southwest of Leo. This part of the sky is well up by nightfall, so you should have no trouble avoiding trees, houses, and other horizon clutter. Daphne, a 125-mile-diameter asteroid, comes to opposition on the first, when it is a 10th-magnitude point of light 1° east of Beta (β) Sextantis. It moves rapidly to the northwest throughout the month, edging by a sparse scattering of 7th- and 8th-magnitude stars before finally crossing into Leo by month's end. You'll need at least a 3-inch telescope and a low-power eyepiece. Simply center the field on the search area using the finder chart and carefully sketch the position of each star you see, especially the faint ones. Come back a night or two later, recenter on the same field, and make your sketch again. The "star" that has shifted position with respect to the background stars is 41 Daphne.






Martin C. Germano

Hunt Down the Leo Trio

With the Milky Way now ringing the horizon, we have a clear view directly up and out of our Galaxy and into deep space overhead. You now have the opportunity to turn your telescope toward Leo to look for other Milky Ways.

If you know where to aim your telescope, you can scoop up three galaxies, M65, M66, and NGC 3628, all in a single low-power field. These spiral galaxies huddle just south of Leo's hindquarters, 2.5° southeast of Theta (τ) Leonis. One of the easiest ways to locate the Leo Trio is to position the field almost exactly between Theta and 4th-magnitude Iota (ι) Leonis.

An eyepiece yielding a 1° field of view shows all three in one view. The two most obvious objects are M65, a 9.3-magnitude bar of misty light on the southeastern edge of the field and M66, a 9th-magnitude oval to the east southeast. Both galaxies have bright nuclei, though of the two, M66's is a tad brighter. Each also shows a milky glowing disk of light. These disks, though not difficult to discern in a 6- or 8-inch telescope, demand a dark sky and clear, haze-free sky conditions if you seek detail within them.

More difficult and often overlooked, NGC 3628 lies north of the brighter pair. This galaxy is an edge-on spiral featuring a broad, equatorial dust band. Because of its larger angular size, NGC 3628 has a low surface brightness and thus not as much eyepiece "presence" as M65 and M66, even though it shines at magnitude 9.5. Still, once you've found it, NGC 3628 is obvious, and one wonders how Charles Messier missed it during his comet searches in the late 18th century.

eastward, away from Jupiter in the sky.

Uranus and Neptune now appear high enough in the sky before dawn that you might want to search for them with a small telescope. Start looking on March 7, when they lie near the waning crescent Moon.

Saturn and Mercury undergo a very close conjunction in the morning sky on March 24. Unfortunately it will be hard to see. When the ecliptic is angled steeply in the evening sky, it forms a shallow angle in the morning sky. On March 24 Saturn comes out of the dawn glare and Mercury plunges back into it. The two planets are only 0.3° apart but stand very low in the southeast shortly before sunup. You may not see them with the unaided eye, but binoculars might make the search worthwhile.

This month's featured asteroid is 41 Daphne, which comes to opposition on March 1. It shines at 10th magnitude in the constellation Sextans (see at left).

Two comets to watch now are Tempel 1, which glows at 11th magnitude in the constellation Virgo, and West-Kohoutek-Ikemura, which glows faintly at about 13th magnitude in eastern Perseus.

March's Planets

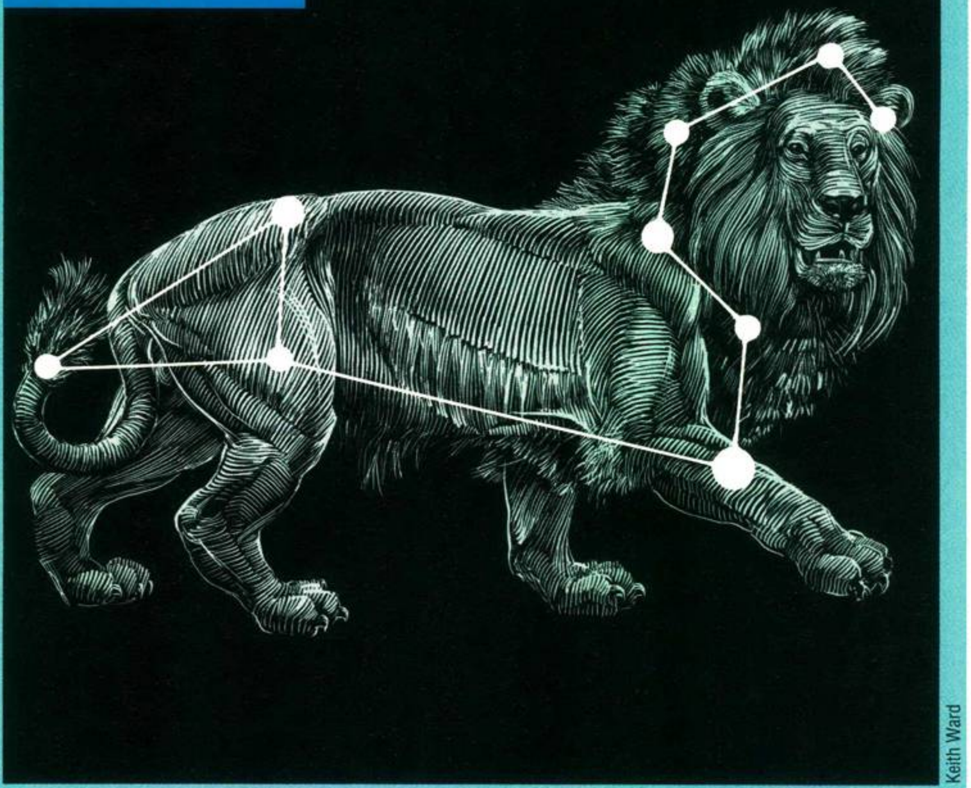
With the exception of Jupiter and elusive Pluto, the planets have been either low in the sky before sunrise or after sunset, or they haven't been visible at all. This month, however, more planets come into view.

Venus doesn't linger for long in the western twilight sky in early March, but it is so brilliant at magnitude –3.9 that you'll see it if you look. This planet has been traveling behind the Sun for the past several months. A telescope shows it as a cream-colored, featureless ball. After this month Venus will climb higher in the evening twilight sky before reaching greatest elongation in August.

When this month begins, **Jupiter**, in Libra, rises before midnight. It rises earlier in the evening every night and by late April surmounts the hori-

THE STARRY SKY

by Deborah Byrd



Keith Ward

Gaze overhead on a clear March evening and you see one of the sky's most majestic constellations, Leo the Lion. You can identify it by looking for a large asterism, or pattern of stars, in the shape of a backwards question mark.

This pattern, called the Sickle, represents the head and shoulders of Leo. Formed of the stars Alpha, Eta, Gamma, Zeta, Mu, and Epsilon Leonis, the Sickle dominates the midevening sky this month. Alpha Leonis, also called Regulus, lies at its base.

Regulus is sometimes called Cor Leonis, the "heart of the Lion." This star shines at magnitude 1.4 and lies 69 light-years away. Because Regulus and the ecliptic are separated by a mere ½°, the Moon and planets often slide past this bright star. Occasionally the Moon passes directly in front of Regulus, an event called an occultation. Bright planets also move past Regulus, but no planets currently inhabit this area.

Algieba (Gamma Leonis) outshines all other stars in the Sickle except Regulus. Algieba, Arabic for the Lion's mane, suggests it marks the neck of Leo. The star shines at magnitude 2.6 and is 76 light-years distant. Like Regulus, Algieba is a double star, both components shining with a yellow tinge.

If you shift your gaze about 20° east of Regulus you'll see a small triangle of stars, an asterism marking the hindquarters of the Lion. The brightest star in this part of Leo, Denebola (Beta Leonis), represents the Lion's tail. Denebola shines brightly at magnitude 2.1.

In its annual journey around the ecliptic, the Sun moves through Leo from about August 10 to September 16. But due to the motion of Earth called precession — a 26,000-year "wobble" of the planet — the Sun once moved through Leo around the time of the June solstice. At the solstice, the Sun reaches its northernmost point in the heavens, reigning supreme in the sky visible from the Northern Hemisphere. That may be why these stars came to be identified with the "king of beasts," a ferocious Lion to match the heat of the summer Sun.

Early Greeks called Leo the Nemean Lion, the offspring of god Zeus and Selene, the Moon goddess. Mythology suggests the Nemean Lion fell to Earth from the Moon. The lion ran rampant on the isthmus of Corinth, killing numerous people and ravaging the land.

A magic creature with an unpenetrable hide, the lion could not be stopped by mortals. The task of killing the lion gravitated to Hercules, who did the deed as the first of his twelve labors. Hercules lifted the beast high before strangling him. The lion's skin became Hercules' cloak, which he wore forever after. Even today, several sky charts show Hercules clothed in a lion's skin.

zon at sunset. Look for the Moon near Jupiter on the morning of March 2 and again on the nights of March 28 and 29. This planet is always a grand sight through a telescope, but we're so relatively close to it now that it's looming particularly large. Jupiter's equatorial diameter is 42".

In early March **Pluto** comes up about half an hour after Jupiter. It is also in the constellation Libra, but at magnitude 13.7 you'll need at least an 8-inch telescope to see it.

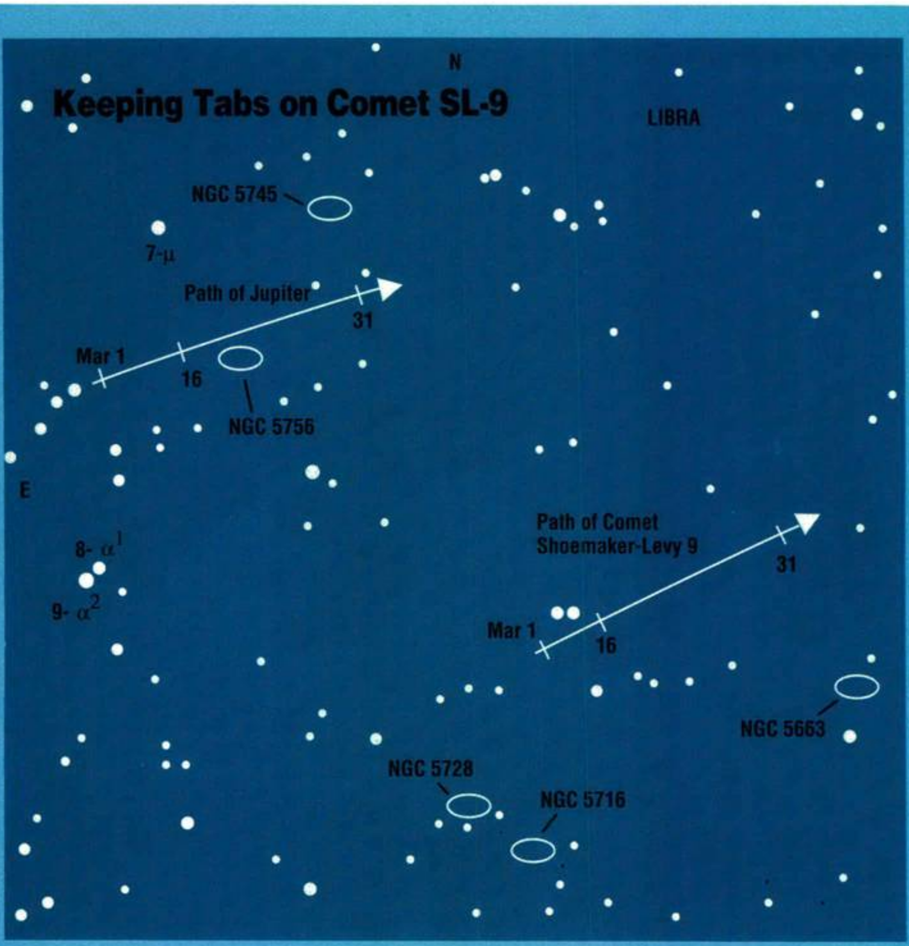
Uranus and **Neptune** both lie in the predawn sky, in the star-rich constellation Sagittarius. Uranus shines at magnitude 5.8 and Neptune at magnitude 8.0.

You can spy **Mercury** in the east before dawn on March 1. It rises about an hour before sunrise on that date and shines at magnitude 1.8. The planet reaches greatest western elongation on March 18, when it is 28° from the Sun. But it's actually a little higher in the sky in the previous week. This is not a good apparition of Mercury. The low angle of the ecliptic makes the planet relatively difficult to see. Scan for Mercury on the morning of March 10, when it is just below the waning crescent Moon.

Mars lies in the predawn sky throughout March, but its relative faintness at magnitude 1.2 combines with the low angle of the ecliptic to make it nearly impossible to see. With optical aid and a clear horizon, you might catch a glimpse of Mars near Saturn early in the month. (See opposite page, top.)

Saturn, the ringed planet, was in conjunction with the Sun, behind the Sun from our earthly vantage point, on February 21. It emerges from the dawn this month, climbing first past Mars and then Mercury. ☐

Deborah Byrd writes and produces the daily "Earth and Sky" radio series. Jeff Kanipe, editor of Star Date *magazine, writes an astronomy column for the Associated Press.*



Keeping Tabs on Comet SL-9

As we go to press astronomers are holding firm to their prediction that Comet Shoemaker-Levy 9 will collide with Jupiter this July. According to astronomers Zdenek Sekanina, Paul W. Chodas, and Donald K. Yeomans, the first fragments will strike Jupiter on July 16, with the central fragments impacting on July 19. The final cometary debris will enter Jupiter's atmosphere on July 22.

The heaviest waves of material in the comet's nuclear train should impact near the beginning and end of this six-day period, with another peak on July 20. Astronomers cannot yet determine the potential energy of the resulting explosions in Jupiter's atmosphere.

Currently, Jupiter rises around 10 p.m. local time. The comet itself is located a couple of degrees southwest of Jupiter, but at magnitude 14 and a feeble surface brightness, it is not an obvious target even in large telescopes. Those of you with CCDs can likely record S-L 9 and its diffuse trail after only a few minutes of integration time. Visual observers with scopes 16-inches or larger in aperture may glimpse the comet on a dark, steady night. The rest of us will have to wait until July 21 to see the effects of the comet's impact.

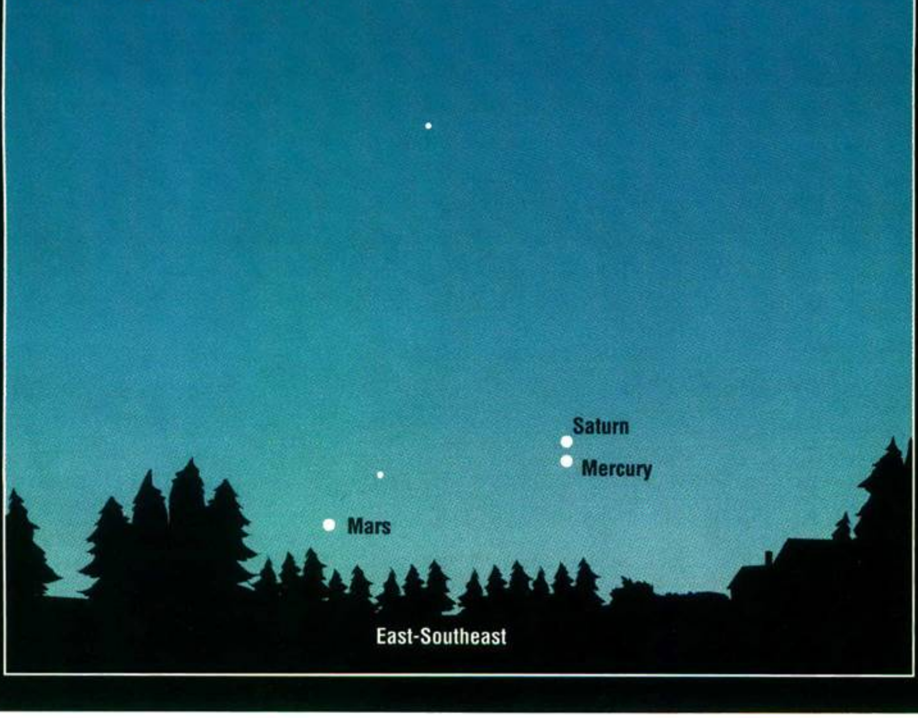
Comet Shoemaker-Levy 9 is currently moving in tandem with Jupiter as it slips out of Libra and heads toward Virgo. By late June, however, both begin to slow and come out of their retrograde motion, turning back toward the east. S-L 9, however, then makes a more decided angle toward Jupiter.

HOW TO FIND SHOEMAKER-LEVY 9

	Offset from Jupiter	
On this date	West in R.A.	South in Dec.
Mar. 1	9m35s	1°22.5'
Mar. 6	9m33s	1°22.4'
Mar. 11	9m31s	1°22.0'
Mar. 16	9m28s	1°21.4'
Mar. 21	9m24s	1°20.6'
Mar. 26	9m19s	1°19.7'
Mar. 31	9m14s	1°18.4'

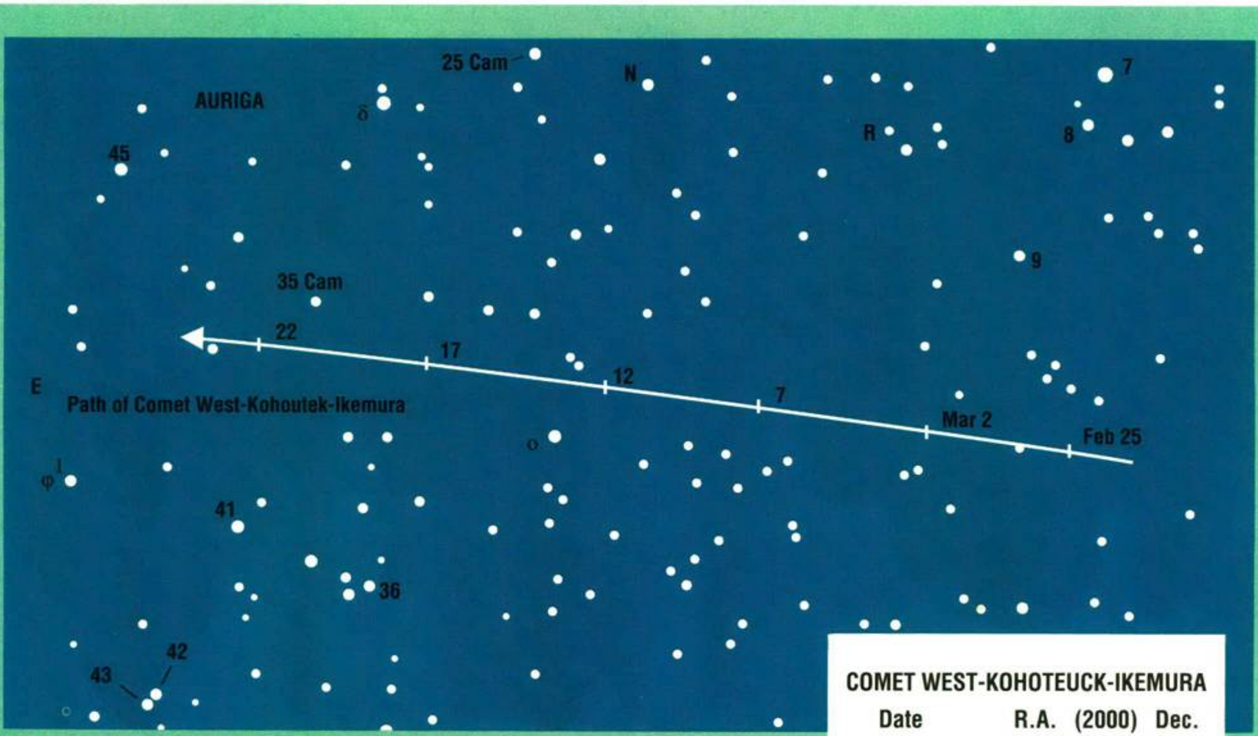
Saturn and Mercury Rise Together

Late morning twilight, March 24



An early morning alignment of bright planets occurs on March 24 when Saturn and Mercury nearly merge above the eastern horizon just before sunrise. Although you don't need a telescope to see this event, a good pair of binoculars will help show you these two planets shining against the gradually brightening twilight. Mercury, the brighter of the two, will be slightly below Saturn. Around 5:50 a.m. local time, the two planets will be less than half a degree apart.

The pair will make it only a few degrees above the horizon before sunrise interferes, so you will need a clear, unobstructed view to the east. The best time to see them should be slightly before 6 a.m. local time. Once you've found the pair of planets, you should be able to follow them for a while, even as the Sun rises.



Following Comet West-Kohoutek-Ikemura

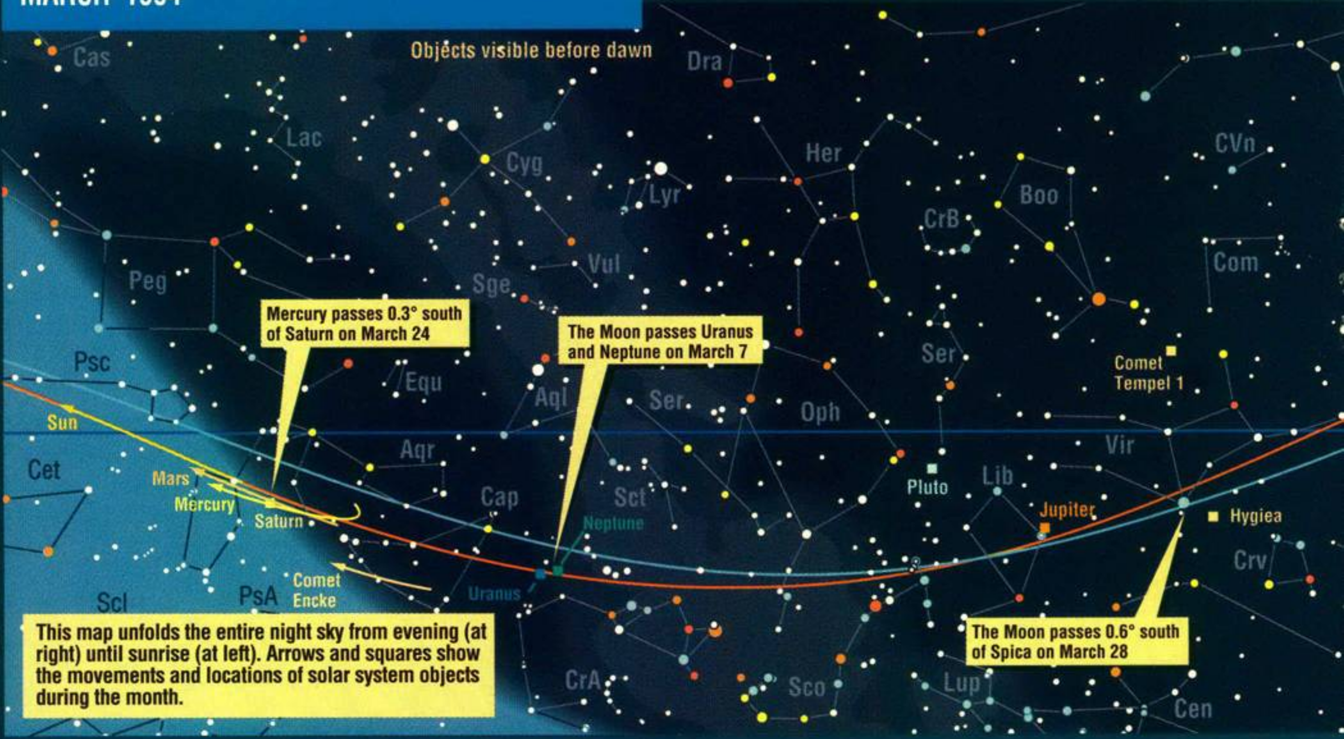
Following a fairly bright apparition in December and January, Comet West-Kohoutek-Ikemura is receding slowly into the outer reaches of the solar system. Currently glowing faintly at about 13th magnitude, the comet is moving northeastward through northern Auriga. Of course, being this faint, and extended to boot, to see it you'll need at least an 8-inch telescope and dark, clear skies. Use the finder chart to help you locate this receding comet.

COMET WEST-KOHOTEUCK-IKEMURA

Date	R.A. (2000)	Dec.
Feb. 25	5h05.0m	48°36'
Mar. 2	5h16.6m	49°23'
Mar. 7	5h29.2m	50°02'
Mar. 12	5h42.5m	50°32'
Mar. 17	5h56.5m	50°54'
Mar. 22	6h11.0m	51°07'

SKY ALMANAC

MARCH 1994

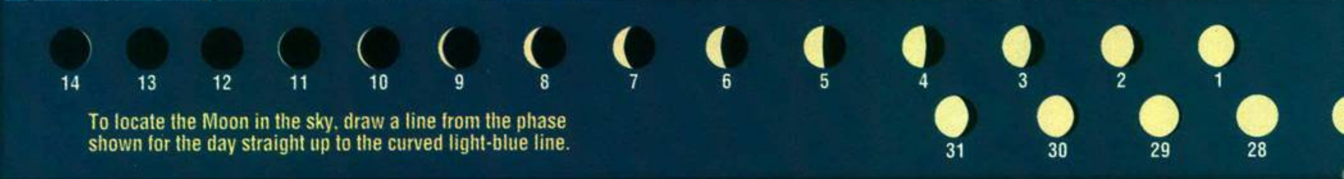

Objects visible before dawn
Cas
Lac
Cyg
Lyr
Dra
Her
CrB
Boo
CVn
Com
Peg
Vul
Sge
Psc
Equ
Aql
Ser
Oph
Ser
Comet Tempel 1
Sun
Cet
Mars
Mercury
Saturn
Aqr
Cap
Sct
Neptune
Uranus
Pluto
Lib
Vir
Jupiter
Hygiea
Crv
Scl
PsA
Comet Encke
CrA
Sco
Lup
Cen

Mercury passes 0.3° south of Saturn on March 24

The Moon passes Uranus and Neptune on March 7

The Moon passes 0.6° south of Spica on March 28

This map unfolds the entire night sky from evening (at right) until sunrise (at left). Arrows and squares show the movements and locations of solar system objects during the month.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9
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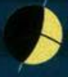
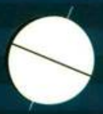
7
6
5
4
3
2
1
31
30
29
28

To locate the Moon in the sky, draw a line from the phase shown for the day straight up to the curved light-blue line.

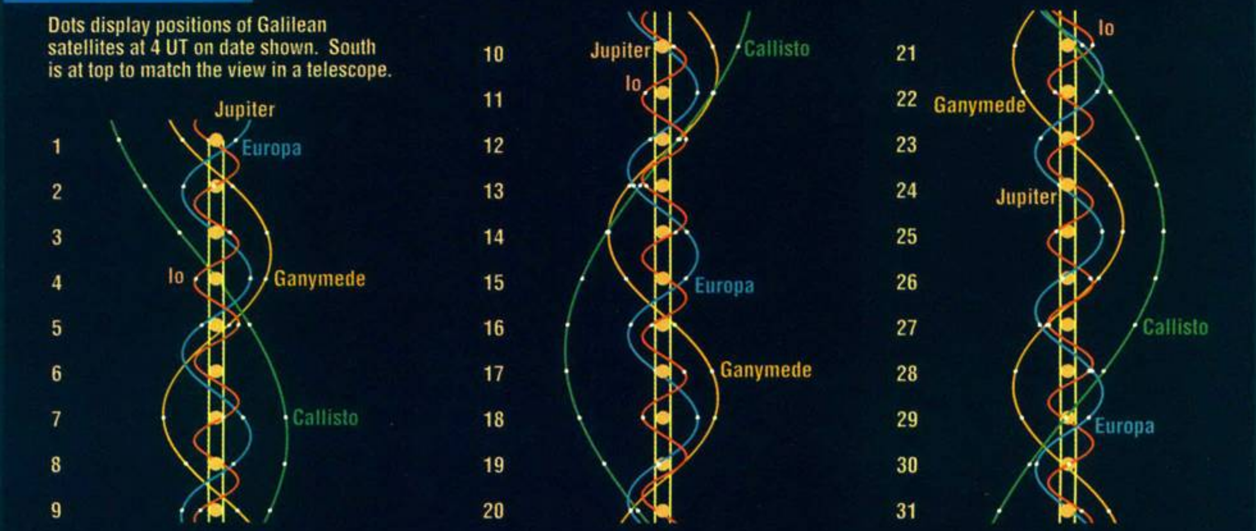
10"

PLANETS	MERCURY	VENUS	MARS
Date	March 15	March 15	March 15
Magnitude	0.3	–3.9	1.2
Angular Size	7.8"	10.1"	4.1"
Illumination	47%	97%	99%
Distance (AU) from Earth	0.857	1.650	2.293
Distance (AU) from Sun	0.457	0.725	1.384
Right Ascension (2000.0)	21h56.9m	0h31.0m	22h32.5m
Declination (2000.0)	–12°52'	2°07'	–10°22'

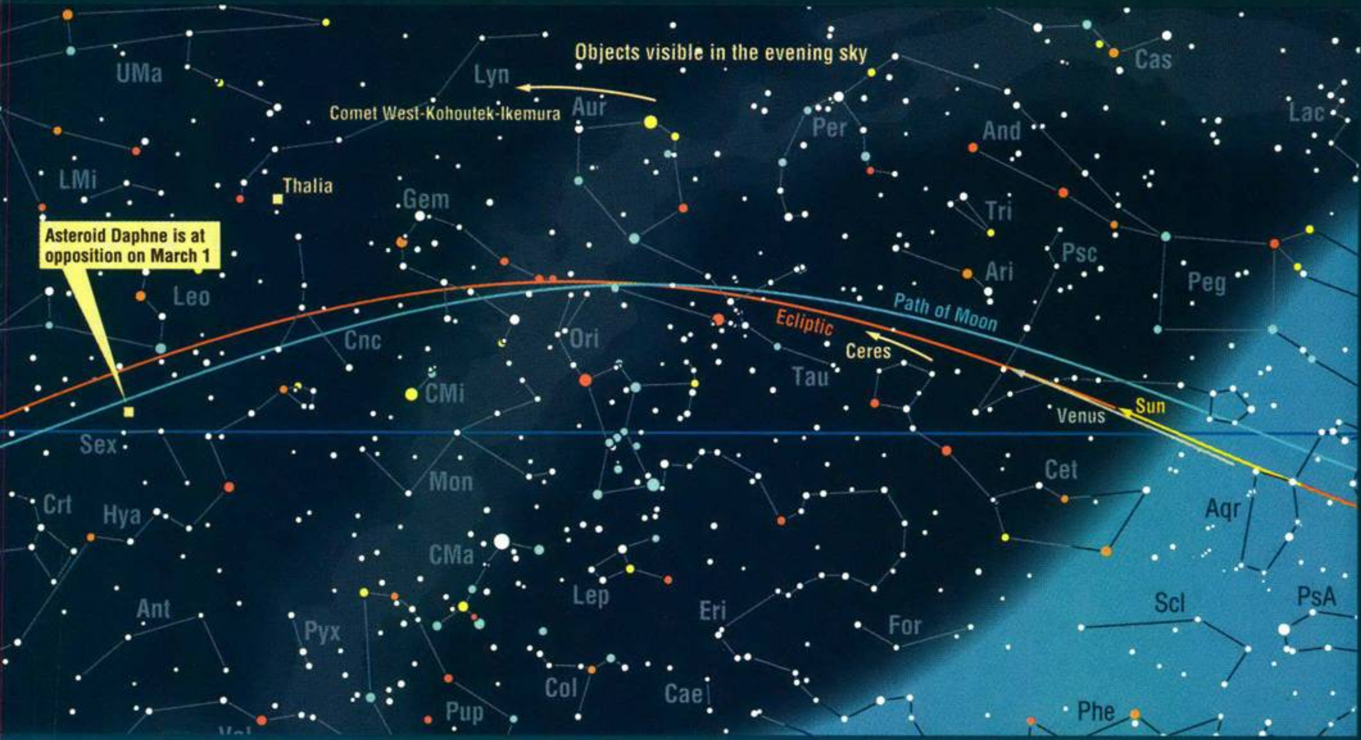




JUPITER'S MOONS



Dots display positions of Galilean satellites at 4 UT on date shown. South is at top to match the view in a telescope.



Objects visible in the evening sky

Asteroid Daphne is at opposition on March 1

UMa
Lyn
Comet West-Kohoutek-Ikemura
Aur
Per
And
Cas
Lac
LMi
Thalia
Gem
Tri
Psc
Peg
Leo
Ari
Path of Moon
Ecliptic
Ceres
Cnc
Ori
Tau
CMi
Venus
Sun
Sex
Mon
Cet
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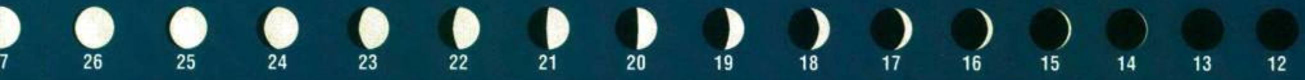
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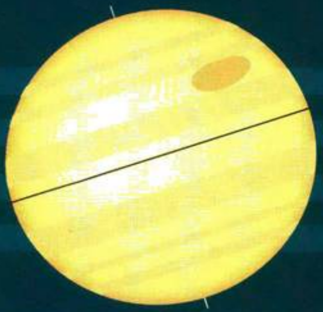
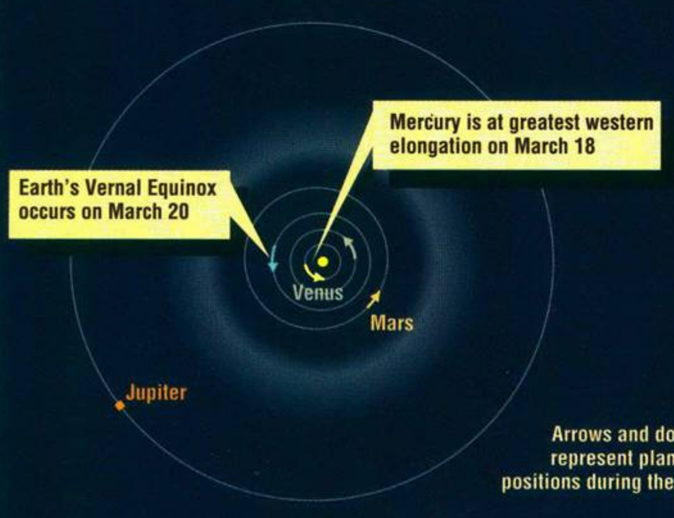


JUPITER	SATURN	URANUS	NEPTUNE	PLUTO
March 15	March 15	March 15	March 15	March 15
–2.3	1.0	5.8	8.0	13.7
41.5"	15.5"	3.5"	2.2"	0.1"
100%	100%	100%	100%	100%
4.746	10.696	20.143	30.645	29.333
5.437	9.760	19.645	30.179	29.771
14h49.1m	22h31.0m	19h50.0m	19h38.4m	15h55.7m
–14°51'	–10°53'	–21°31'	–20°54'	–5°50'

THE PLANETS IN THEIR ORBITS

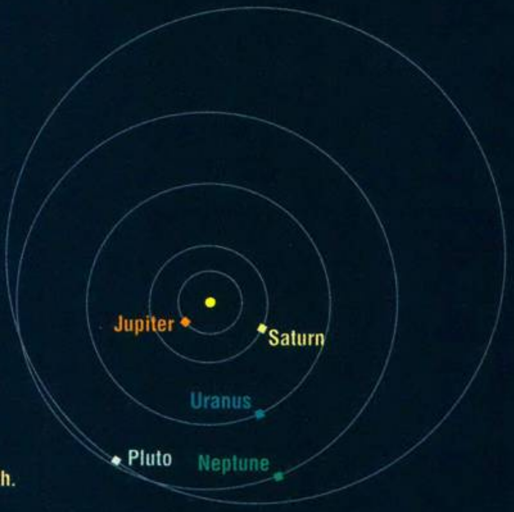


Mercury is at greatest western elongation on March 18

Earth's Vernal Equinox occurs on March 20

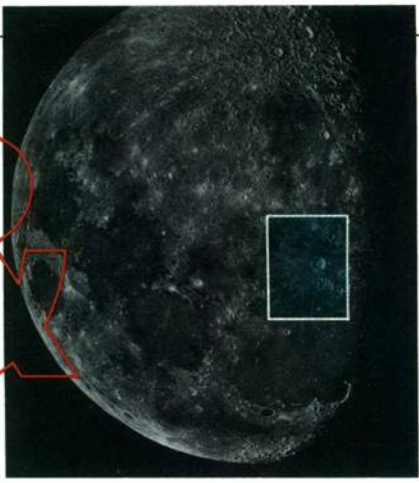
Venus
Mars
Jupiter

Arrows and dots represent planets' positions during the month.


Jupiter
Saturn
Uranus
Pluto
Neptune

MOON OBSERVER'S NOTEBOOK

COPERNICUS & MARE INSULARUM



Lick Observatory

EARLY MORNING SUN THROWS Copernicus and its surroundings into bold relief.

Most of the Moon's past is on display in the region around Copernicus.

by Michael T. Kitt

The Moon wears its history on its face. Impacts, lava floods, and gassy eruptions have left their marks upon it for ages. You can find such events recorded everywhere on the Moon, but for seekers of lunar antiquity the region around Copernicus is among the best. Why? Because here lie the fragmentary remains of one of the nearside's oldest impact basins.

Copernicus itself, however, is one of the Moon's youngest craters. Born 800 million years ago — just yesterday in lunar terms — Copernicus offers more rich detail than anyone can take in at once. Even the smallest telescope reveals a panorama that changes dramatically night by night. Copernicus is a shallow saucer 93 kilometers across but only 3.8 km deep. It's so fresh that it has lent its name to the most recent of the Moon's five geological periods.

Nine evenings after New Moon, the Sun's rays first touch the crater's rim peaks. Over several hours the lit points grow and merge into a ring of light circling a hexagonal pool of shadow. Lunar sunrise is also a good time to look for secondary craters from Copernicus. These were gouged by house-sized rocks that rained down on the landscape, blasting small, shallow craters best seen in grazing light. (Some lie in herringbone patterns whose V always points back toward Copernicus.) At moments of excellent seeing, hundreds of craterlets suddenly pop into view, providing a breathtaking effect worth waiting for. Closer to Copernicus look for the hummocky ejecta blanket created when a turbulent flow of gas and debris shot out from the impact at ground level.

Ten nights after New Moon, explore the terraces and ravines inside the western wall. Terraces are huge landslips where long portions of wall collapsed. Under high power you'll see a wealth of detail in them.

A day later, focus on the floor of Copernicus, flooded by impact-melted rock. Note the different texture in the northwestern portion, fairly smooth and featureless compared to the rougher southern and eastern parts, where broken pieces of lunar crust lie jumbled with impact melt. Copernicus is much shallower today than at the moment of impact; scientists think its original cavity was some 7 or 8 km deep. But immediately after the impact the crust rebounded, tossing up the crater's three central peaks. These may be samples of deep lunar crust (or even mantle) dredged up from about 10 km down.

As Full Moon approaches, lovely, intricate rays emerge around Copernicus in all their glory. The impact sprayed millions of tons of pulverized rock for hundreds of kilometers. While most rays run dead straight, some fell in looped patterns, one nested inside the other: Look two diameters southeast of the crater. In the west, Copernican rays merge into those from Kepler.

Just east of Copernicus lies **Stadius**, a 69-km-diameter "ghost crater" that's all but eradicated. Lava flows in **Sinus Aestuum** have covered it except for a small arc of rim still preserved in the northeast, where it joins a group of low hills near Eratosthenes. The craterlets sprinkled across it are mostly secondaries from Copernicus.

Were Stadius better preserved, it would probably rival **Eratosthenes**. In appearance, though, Eratosthenes is a "little Copernicus," 58 km across. Its interior walls show similar slumps and terraces, and debris mingles with smooth pools of impact melt on the floor around its central peak.

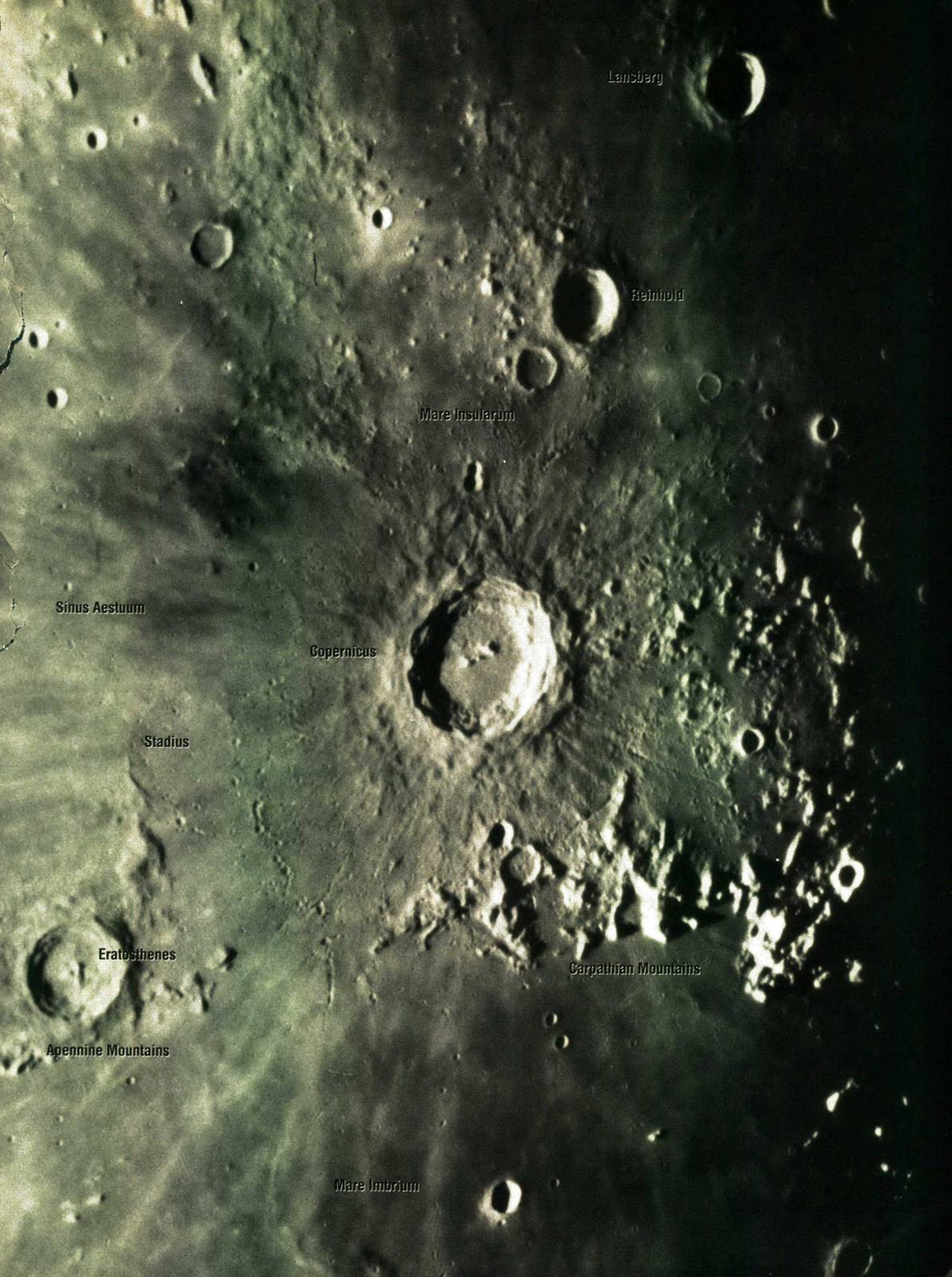
Because its rays have nearly vanished, scientists think Eratosthenes is older than Copernicus — but it is clearly younger than the lavas of **Mare Imbrium**. The mare fills an impact basin whose rim is marked near Copernicus by the Apennine *and the* Carpathian mountains. Scientists think the Imbrium impact occurred some 3.85 billion years ago, while the lavas of Mare Imbrium, Sinus Aestuum, and **Mare Insularum** are millions of years younger.

The Imbrium basin reaches far into the Moon's past. But here and there you can spot faint traces of a still-older topography. The ancient Insularum basin has only two almost-eradicated rings left: **Lansberg** lies atop the outer one, while **Reinhold** stands just north of the inner. To trace the basin, use low magnification — plus some imagination! — and look for concentric rings of broken hills encircling Copernicus at distances of 300 and 500 km.

How old is the Insularum basin? Scientists can't say, except that it's among the most ancient known. How ironic it is, then, that two major impact features — one almost lost in lunar antiquity, the other dating from just yesteryear — should both fall on the same piece of lunar real estate. ☐

Michael T. Kitt is an experienced lunar observer and the author of The Moon: An Observing Guide for Backyard Telescopes *(Kalmbach, 1992).*

Christian Viladrich


Lansberg
Reinhold
Mare Insularum
Sinus Aestuum
Copernicus
Stadius
Eratosthenes
Carpathian Mountains
Apennine Mountains
Mare Imbrium

Taking the Deep-Sky Plunge

Are you ready to dive into the depths of space? Here's how to do it the easy way.

by Alister Ling

Exploring galaxies, nebulae, faint star clusters — all the delights of deep-sky observing — is an enormous thrill because it takes you on a journey of the imagination far from Earth. It can also be an enormous challenge.

The first step in deep-sky observing is getting to the right place in the sky. While computerized telescopes make this pretty easy, that equipment is pricey. Most stargazers use a good set of maps. What you want is something that takes you easily from the stars you can spot by naked eye to the objects you need your telescope to see. Many backyard astronomers find Wil Tirion's *Sky Atlas 2000.0* just right for this.

Start with the Star Dome map in Sky Almanac and locate in the sky the constellation you want to explore. Then turn to the *Sky Atlas* chart that plots the deep-sky objects in the constellation. (Or do it the other way around: browse through *Sky Atlas* plates for interesting regions, find the nearest naked-eye stars, and then locate them on the Star Dome map.)

The jump from the naked-eye view to even a low-power telescope view is usually too big to make in one go, however. That's why you need a finderscope. Align it by centering a distant landmark or a bright object on the horizon in the field of a low-power eyepiece in the main scope. Adjust the centering screws on the finder until its crosshair lines up with the target in the main scope. Then shift to a high-power eyepiece and improve the alignment. Take whatever time you need to get the finder aimed parallel to the main scope.

Eagle Nebula

Jack Newton

It helps to know how much sky your finder sees. So trace a circle that shows the finder's field of view on a transparent sheet of plastic. (To determine this, check the Belt of Orion or the Bowl of the Big Dipper.)

M41

Luke Dodd

You may want to try a "zero-power" finder such as a Telrad or Tele Vue's Starbeam. These project a glowing bull's-eye or a spot on the sky. Just aim the spot at the place indicated on your chart and you're there.

What Should I Look For?

Start with the M objects — "M" for Messier (messy-yay). French astronomer Charles Messier stumbled upon these galaxies, nebulae, and star clusters 200 years ago while sweeping for comets. They're pretty much the 110 best deep-sky objects. (A few showpieces that Messier missed ended up in the *New General Catalogue* or NGC.)

What these will look like through your scope depends on its size and the sky conditions. If you live near a city, you'll be lucky to see the Great Galaxy in Andromeda (M31) as more than a smudge. The problem is that both galaxies and nebulae are patches of gray on a gray sky. Other objects, however, are easier to see

Star clusters like M41 in Canis Major shine through the veil of light pollution because their individual stars are bright. Globular clusters like M3 in Canes Venatici are good targets too because they have lots of stars confined to a small region. Planetary nebulae are also relatively easy to spot. They are roundish puffs of gas often showing a disk that resembles a faint planet. They range from big and very faint to small and relatively bright; most have a high surface brightness. For example, the Ring Nebula in Lyra (M57) is visible from city sites, as are the Blue Snowball in Andromeda (NGC 7662) and the Cat's Eye in Draco (NGC 6543).

M3

Mansfield Clinnick

Dark Adaptation

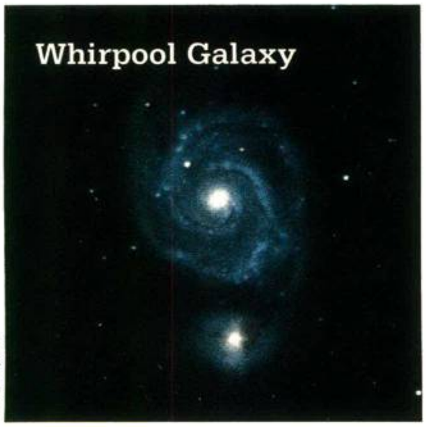
From a dark rural site, all objects appear brighter and better. In the dark, your eye becomes vastly more sensitive to low light due to chemical changes in the receptors called rods. It takes 10 to 15 minutes to reach a reasonable level of sensitivity. However your eye continues to dark-adapt even after 30 minutes.

Under dark skies, be jealous of your eyes' sensitivity. If you briefly look at Jupiter or the crescent Moon before looking at a galaxy, you won't see as much because the bright light sets you back. From suburbia, however, light pollution prevents your eye from dark-adapting all the way. Under these conditions, don't worry about walking back into a well-lit house — it'll delay your dark adaptation only about 10 minutes because conditions won't let you dark-adapt much further anyway.

Lagoon Nebula

Jack Newton

I recommend you carry two red-lensed flashlights — a brighter one for setting up or searching for tools and a faint one for chart reading. Dim the latter as much as possible and cover your observing eye when you scan a chart. Some observers wear hoods, towels, or eye-patches. (And don't forget to cover or turn off your vehicle's trunk and dome lights.)



Larry Myers

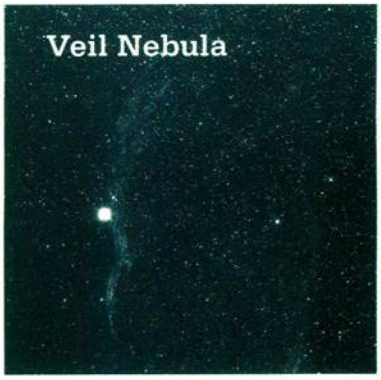
Averted Vision

The most useful technique to learn is averted vision. The trick is to look off to one side of the field of view but pay attention to the middle. This places the image on your retina's most light-sensitive area. Experiment with averted vision on the Eskimo Nebula (NGC 2392) in Gemini. This planetary nebula is a faint circular glow surrounding a star. When you look directly at the central star, the nebula disappears. You look away — and it returns! Also, peripheral vision is very sensitive to motion. This is why veteran observers tap the tube gently to rock the scope when they want to detect a faint galaxy.

To see color in a bright object like the Orion Nebula (M42), you have to look straight at it without averted vision so that the light falls on the retina's color-sensitive cones. Mostly you'll see green, but larger telescopes collect enough light to stimulate your red or purple detectors slightly.

Magnification and Details

You sometimes hear that an f/5 telescope gives brighter images than an f/10. But so long as the aperture and magnification are the same, the brightness will be too. A second myth is that "low power is best." It's true that low magnification produces a bright image and wide fields of view that are fantastic for sweeping the Milky Way. But if you want to see the dust lanes in a galaxy, go for high power.



Franz Klauser

Increasing the power spreads out the object's light, but that's okay since larger faint objects are easier to detect than smaller faint objects. Also, at low power many galaxies like the Whirlpool (M51) in Canes Venatici are surrounded by a wide field of bright sky. By choosing a magnification that just frames the galaxy, you darken the sky a bit and make the galaxy easier to see.

Objects with high surface brightnesses are fine at high power. For example, small open and globular clusters as well as planetary nebulae can be outstanding at 250x or more. The atmosphere's steadiness is usually the limiting factor.

Above all, be patient. At first your eye doesn't know what it's looking for. If your scope has no drive, you must learn to move it smoothly and pick out details one piece at a time as the object slides through the field of view. If you get frustrated, take a break. Hey, what's your hurry?

Nebula Filters

Nebula and light-pollution filters *work*. They block manmade light and allow emission nebulae to shine through. They don't help as much, however, on reflection nebulae, star clusters, or galaxies.

You can get wonderful gains on emission nebulae by using narrow-band filters such as Orion's Ultrablock and Lumicon's UHC or O III filters. The Veil Nebula in Cygnus will stand out clearly, its arcs glowing against a black sky. Previously invisible swaths of nebulosity surrounding the Lagoon, Eagle, and Omega nebulae suddenly become obvious.

Keep in mind that you must shade your eye by cupping your hands or using a dark cloth. Otherwise, stray light enters the eyepiece, bounces off the filter, and overwhelms your object. (For more information, see "ASTRONOMY Tests Ten Nebula Filters," February 1991.)

Take Your Time

Your best ally in deep-sky observing is practice. I find that sketching what I see sharpens my skills by pushing me to look for detail.

Plan to spend about ten minutes on each faint object and 20 or more on complex ones such as the Veil or the Orion Nebula. Becoming a keen-eyed deep-sky observer isn't difficult. With some knowledge and a few easily acquired skills under your belt, you'll advance so quickly you'll swear that the sky conditions have definitely improved since you began! ☐

Ring Nebula

Rob Luffel

Alister Ling frequently contributes to ASTRONOMY. He always tries to get the most out of his scopes — big or small.

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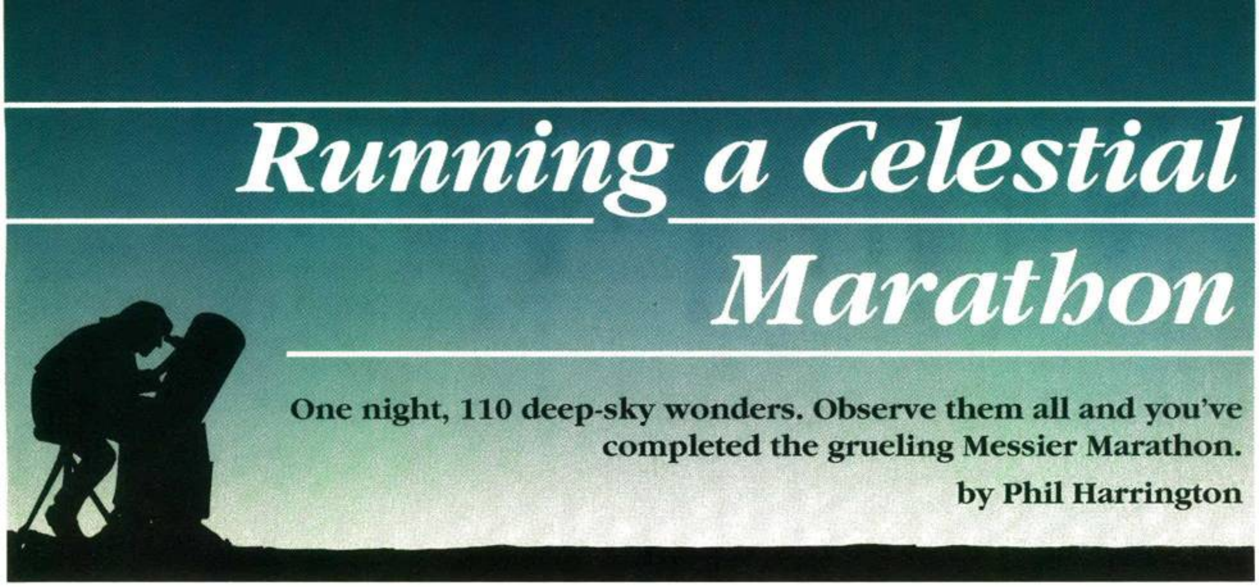
Running a Celestial Marathon



One night, 110 deep-sky wonders. Observe them all and you've completed the grueling Messier Marathon.

by Phil Harrington

My heart beats a little faster as adrenalin hits my blood stream. Thoughts race through my mind at an even faster pace. "Will my plan of attack work? Will I make it to the finish line this time?"

No, I'm not a finely conditioned athlete preparing for a three-hour run over 26 miles 385 yards of city pavement. I'm a backyard astronomer anticipating the start of our hobby's answer to the ultimate road race: the Messier Marathon.

The goal — observe in one night the more than 100 deep-sky objects catalogued by 18th-century French astronomer Charles Messier and his associate Pierre Méchain. You can do this only once each year, in the latter half of March, when the Sun lies in a part of the sky devoid of Messier objects. That's what makes it possible to spy every Messier object in a single sunset-to-sunrise observing session. Like our counterparts in the world of track, however, you can't hope to be a successful Messier Marathoner if you aren't prepared.

Pre-race Strategy

First, choose a night around New Moon when bright moonlight won't hinder your view. (For 1994 the best time is just after New Moon in mid-March.) Second, pick an observing site with clear, dark skies and an unobstructed view in all directions. Pay particular attention to the view toward the northwest and southeast, where you must locate several objects low in the sky just after evening twilight ends and before morning twilight begins. I've had good luck using golf courses, parks, open fields, and the tops of hills. Check beforehand to see whether access to the area is restricted at night.

But you need more than a dark night and a good site to reach the marathon's finish line. Here's what I bring along to make it through the long and often cold night under the stars: a telescope, eyepieces, a detailed star atlas, binoculars, a red flashlight, a clipboard, a pen or pencil, a checklist of Messier objects listed sequentially, a wrist watch or clock, cold-weather clothing, a chair or stool, a table, a thermos of hot chocolate, coffee, or tea, and some munchies.

You don't need a large or sophisticated telescope as your marathon partner. (Remember that Messier used no more than an 8-inch telescope when he catalogued the objects.) You can even use binoculars for a Messier Marathon. From a dark-sky site in 1991, I found 101 Messier objects with a pair of 11x80 glasses. Years earlier I viewed 85 M-objects from a suburban observing locale using just 7x35 binoculars.

You also must be familiar with the telescope you'll be using. Just as a marathon runner wouldn't dream of breaking in a new pair of shoes on race day, you don't want to be fumbling around with a new telescope on your marathon.

This brings up a hot debate of Messier Marathoning: Most marathoners abhor computerized telescopes! Likewise, they shun setting circles and other mechanical aids. Instead, they rely only on their eyes, a star atlas, a finder (perhaps binoculars to augment the finder), and a telescope.

Regardless of the telescope, use no less than an 8x50 finderscope. Smaller finders don't reveal enough stars to get you quickly and easily to your targets.

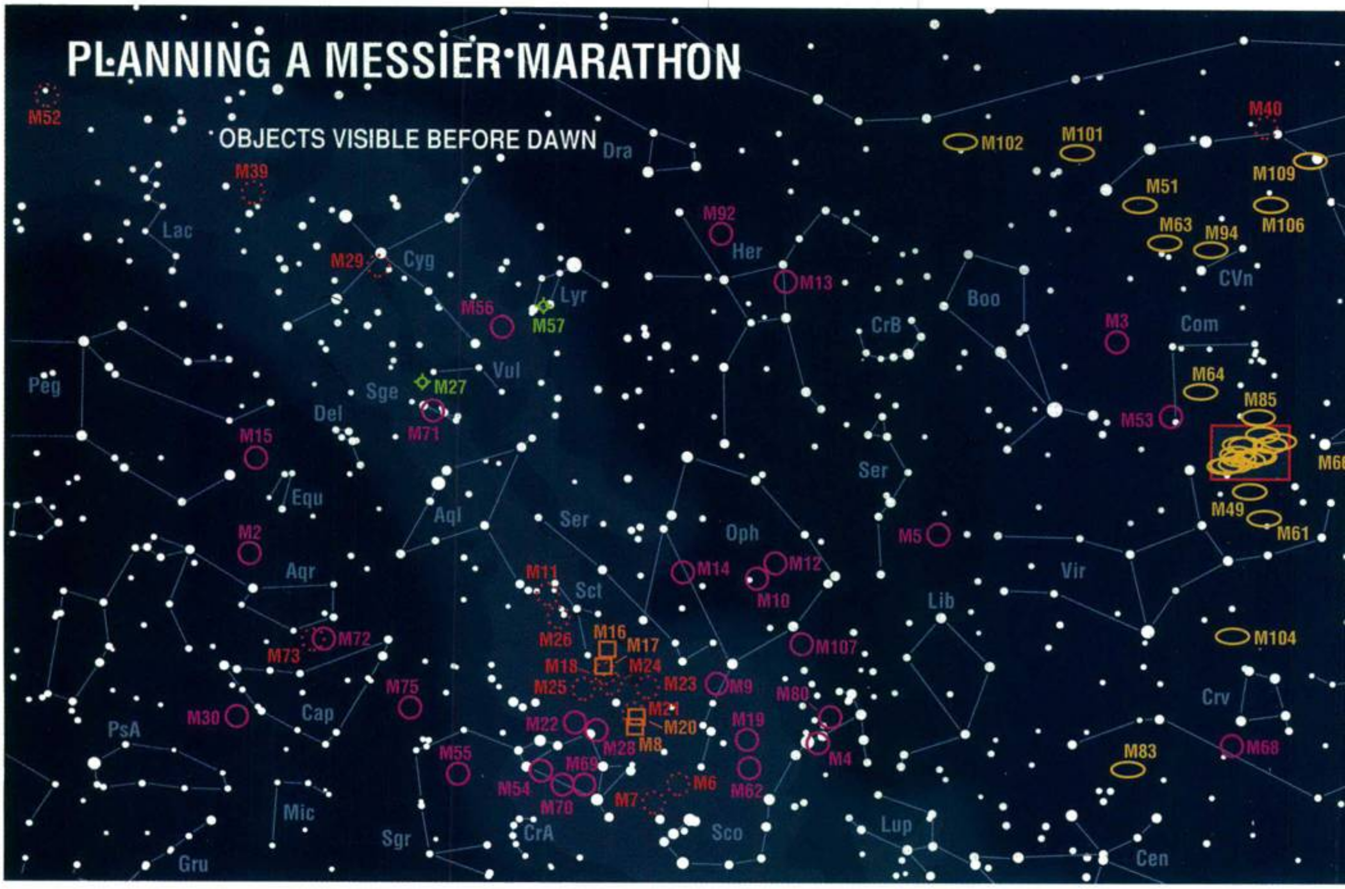
(continued on page 64)

Planetary Nebula — M76

Jack Marling

PLANNING A MESSIER MARATHON

OBJECTS VISIBLE BEFORE DAWN


M52
M39
Lac
Dra
M92
Her
M13
M102
M101
M40
M109
M51
M106
M63
M94
CVn
M29
Cyg
M56
Lyr
M57
Boo
CrB
M3
Com
Vul
M27
Sge
Peg
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M71
M64
M85
M53
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M61
M2
M5
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M14
M12
M10
Vir
Lib
M72
M73
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M16
M17
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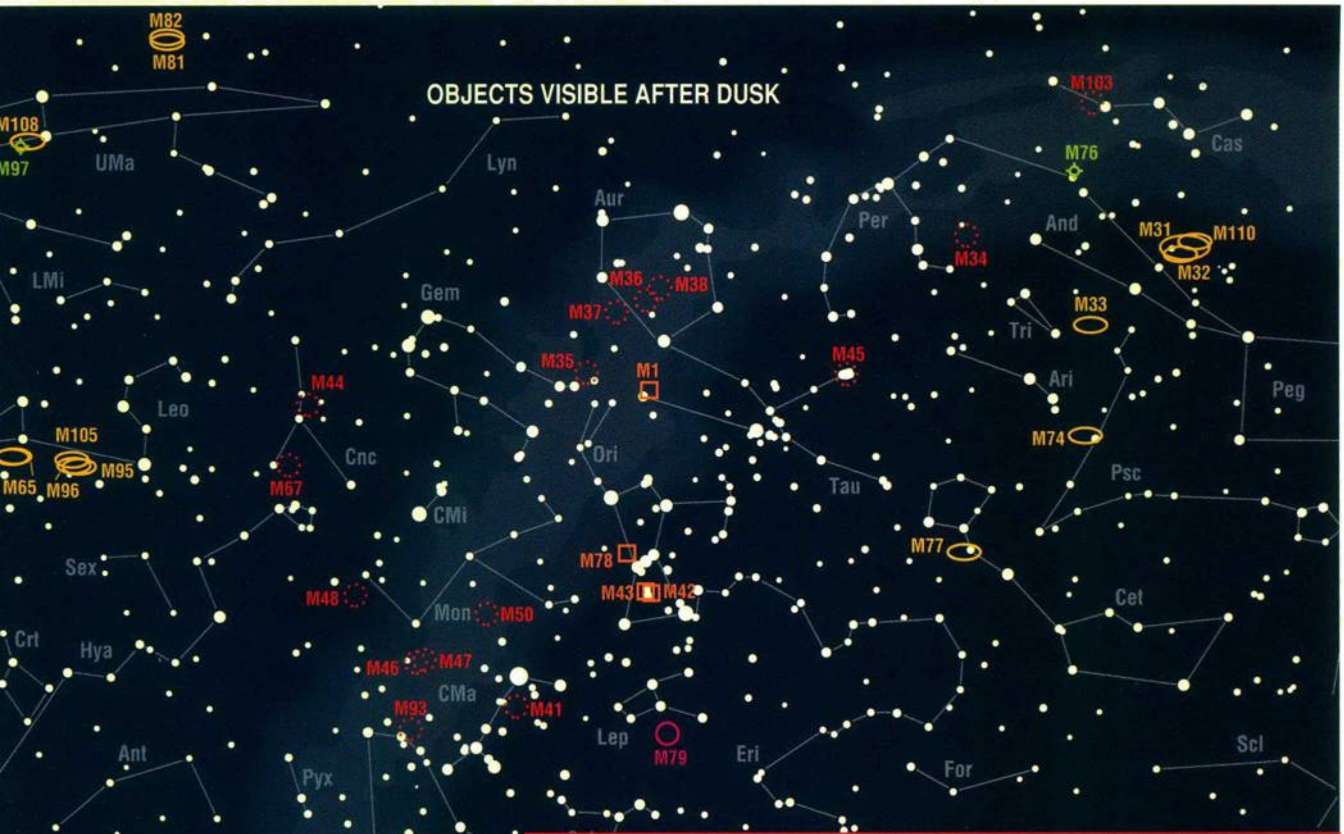
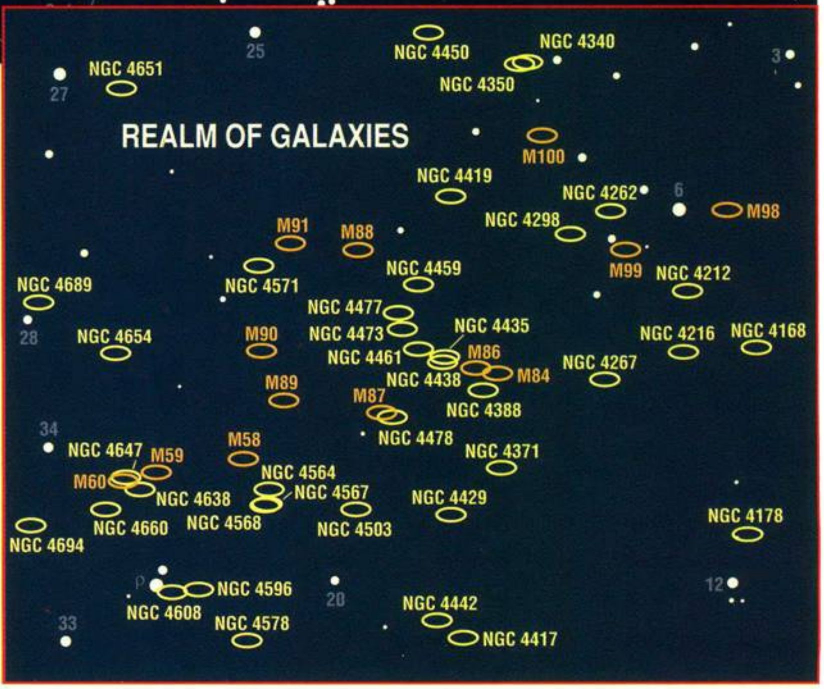
M24
M25
M23
M9
M80
M107
M104
M75
Crv
M30
Cap
M22
M21
M20
M28
M8
M19
M4
PsA
M55
M69
M83
M68
M54
M70
M7
M6
M62
Mic
Sgr
CrA
Sco
Lup
Cen
Gru

ASTRONOMY: Steven G. Davis

Order #	Messier #	Con.	RA (2000.0)	Dec.	Type	Mag.	Size
1	M45	Tau	3h47.0m	24°07'	OC	1.2	110
2	M42	Ori	5h35.4m	–5°27'	DN	—	66x60
3	M43	Ori	5h35.6m	–5°16'	DN	—	20x15
4	M41	CMa	6h47.0m	–20°44'	OC	4.5	38
5	M35	Gem	6h08.9m	24°20'	OC	5.1	28
6	M31	And	0h42.7m	41°16'	Gal	3.5	178x63
7	M32	And	0h42.7m	40°52'	Gal	8.2	8x6
8	M110	And	0h40.4m	41°41'	Gal	8.0	17x10
9	M77	Cet	2h42.7m	–0°01'	Gal	8.8	7x6
10	M33	Tri	1h33.9m	30°39'	Gal	5.7	62x39
11	M79	Lep	5h24.5m	–24°33'	GC	8.0	9
12	M74	Psc	1h36.7m	15°47'	Gal	9.2	10x10
13	M76	Per	1h42.4m	51°34'	PN	12.2*	1
14	M52	Cas	23h24.2m	61°35'	OC	6.9	13
15	M103	Cas	1h33.2m	60°42'	OC	7.4	6
16	M34	Per	2h42.0m	42°47'	OC	5.2	35
17	M38	Aur	5h28.7m	35°50'	OC	6.4	21
18	M36	Aur	5h36.1m	34°08'	OC	6.0	12
19	M37	Aur	5h52.4m	32°33'	OC	5.6	24
20	M1	Tau	5h34.5m	22°01'	DN	—	6x4
21	M78	Ori	5h46.7m	0°03'	DN	—	8x6
22	M50	Mon	7h03.2m	–8°20'	OC	5.9	16
23	M47	Pup	7h36.6m	–14°30'	OC	4.4	30
24	M46	Pup	7h41.8m	–14°49'	OC	6.1	27
25	M93	Pup	7h44.6m	–23°52'	OC	6.2	22
26	M48	Hya.	8h13.8m	–5°48'	OC	5.8	54
27	M44	Cnc	8h40.1m	19°59'	OC	3.1	95
28	M67	Cnc	8h50.4m	11°49'	OC	6.9	30
29	M81	UMa	9h55.6m	69°04'	Gal	6.9	26x14
30	M82	UMa	9h55.8m	69°41'	Gal	8.4	11x5
31	M108	UMa	11h11.5m	55°40'	Gal	10.1	8x3
32	M97	UMa	11h14.8m	55°01'	PN	12.0*	3
33	*M109*	*UMa*	11h57.6m	53°23'	Gal	9.8	8x5
34	M40	UMa	12h22.4m	58°05'	DS	8.0	1
35	M106	CVn	12h19.0m	47°18'	Gal	8.3	18x8
36	M94	CVn	12h50.9m	41°07'	Gal	8.2	11x9
37	M63	CVn	13h15.8m	42°02'	Gal	8.6	12x8
38	M51	CVn	13h29.9m	47°12'	Gal	8.4	11x8
39	M101	UMa	14h03.2m	54°21'	Gal	7.7	27x26
40	M95	Leo	10h44.0m	11°42'	Gal	9.7	7x5
41	M96	Leo	10h46.8m	11°49'	Gal	9.2	7x5
42	M105	Leo	10h47.8m	12°35'	Gal	9.3	5x4
43	M65	Leo	11h18.9m	13°05'	Gal	9.3	10x3
44	M66	Leo	11h20.2m	12°59'	Gal	9.0	9x4
45	M98	Com	12h13.8m	14°54'	Gal	10.1	10x3
46	M99	Com	12h18.8m	14°25'	Gal	9.8	5x5
47	M100	Com	12h22.9m	15°49'	Gal	9.4	7x6
48	M85	Com	12h25.4m	18°11'	Gal	9.2	7x5
49	M84	Vir	12h25.1m	12°53'	Gal	9.3	5x4
50	M86	Vir	12h26.2m	12°57'	Gal	9.2	7x6
51	M87	VIr	12h30.8m	12°24'	Gal	8.6	7x7
52	M89	Vir	12h35.7m	12°33'	Gal	9.8	4x4
53	M90	Vir	12h36.8m	13°10'	Gal	9.5	10x5
54	M88	Com	12h32.0m	14°25'	Gal	9.5	7x4
55	M91	Com	12h35.4m	14°30'	Gal	10.2	5x4
56	M58	Vir	12h37.7m	11°49'	Gal	9.8	5x4
57	M59	Vir	12h42.0m	11°39'	Gal	9.8	5x3
58	M60	Vir	12h43.7m	11°33'	Gal	8.8	7x6
59	M49	Vir	12h29.8m	8°00'	Gal	8.4	9x7
60	M61	Vir	12h21.9m	4°28'	Gal	9.7	6x6
61	M53	Com	13h12.9m	18°10'	GC	7.7	13
62	M64	Com	12h56.7m	21°41'	Gal	8.5	9x5
63	M3	CVn	13h42.2m	28°23'	GC	6.4	16
64	M104	Vir	12h40.0m	–11°37'	Gal	8.3	9x4
65	M68	Hya	12h39.5m	–26°45'	GC	8.2	12
66	M83	Hya	13h37.0m	–29°52'	Gal	8.0	11x10
67	M5	Ser	15h18.6m	2°05'	GC	5.8	17
68	M102	Dra	15h06.5m	55°46'	Gal	10.0	5x2
69	M13	Her	16h41.7m	36°28'	GC	5.9	17
70	M92	Her	17h17.1m	43°08'	GC	6.5	11
71	M12	Oph	16h47.2m	–1°57'	GC	6.6	15
72	M10	Oph	16h57.1m	–4°06'	GC	6.6	15
73	M14	Oph	17h37.6m	–3°15'	GC	7.6	12
74	M107	Oph	16h32.5m	–13°03'	GC	8.1	10
75	M4	Sco	16h23.6m	–26°32'	GC	5.9	26
76	M80	Sco	16h17.0m	–22°59'	GC	7.2	9
77	M62	Oph	17h01.2m	–30°07'	GC	6.6	14
78	M19	Oph	17h02.6m	–26°16'	GC	7.2	14
79	M9	Oph	17h19.2m	–18°31'	GC	7.9	9
80	M6	Sco	17h40.1m	–32°13'	OC	4.2	15
81	M7	Sco	17h53.9m	–34°49'	OC	3.3	80
82	M8	Sgr	18h03.8m	–24°23'	DN	—	90x40
83	M20	Sgr	18h02.6m	–23°02'	DN	—	29x27
84	M21	Sgr	18h04.6m	–22°30'	OC	5.9	13


OBJECTS VISIBLE AFTER DUSK
M82
M81
M108
M97
UMa
LMi
Lyn
Aur
Gem
M36
M38
M37
M35
M1
M45
Per
M34
M103
M76
Cas
And
M31
M110
M32
M33
Tri
Ari
Peg
Leo
M44
Cnc
M105
M95
M65
M96
M67
CMi
Ori
Tau
M74
Psc
M77
Sex
M78
M43
M42
M48
Mon
M50
Cet
Crt
Hya
M46
M47
CMa
M93
M41
Lep
M79
Eri
For
Scl
Ant
Pyx
Vel
Pup


REALM OF GALAXIES
NGC 4651
27
25
NGC 4450
NGC 4340
NGC 4350
3
M100
NGC 4419
NGC 4262
6
M98
NGC 4298
M91
M88
M99
NGC 4212
NGC 4459
NGC 4689
NGC 4571
NGC 4477
NGC 4473
NGC 4435
NGC 4216
NGC 4168
28
NGC 4654
M90
NGC 4461
M86
M84
NGC 4267
NGC 4438
M89
M87
NGC 4388
34
NGC 4478
NGC 4647
M59
M58
NGC 4371
M60
NGC 4564
NGC 4567
NGC 4429
NGC 4638
NGC 4178
NGC 4660
NGC 4568
NGC 4503
NGC 4694
ρ
NGC 4596
20
12
NGC 4608
NGC 4442
33
NGC 4578
NGC 4417

THE MESSIER MARATHON REQUIRES speed and endurance — speed to spot many objects just after dusk and just before dawn and endurance to keep observing all night. The Realm of Galaxies in Virgo and Coma Berenices (right) is the marathon's Heartbreak Hill.

RA and Dec: Right ascension and declination for epoch 2000.0. **Type:** OC = open cluster, GC = globular cluster, DN = diffuse nebula, PN = planetary nebula, Gal = galaxy, DS = double star, SC = star cloud. **Mag.:** visual (V) magnitude, those with asterisks are photographic magnitudes. **Size:** in arcminutes.

Objects 1 to 5 should be found before twilight ends

Objects 6 to 12 are early evening objects

Objects 104 to 110 are late morning objects

Order #	Messier #	Con.	RA (2000.0)	Dec.	Type	Mag.	Size
85	M23	Sgr	17h56.8m	−19°01'	OC	5.5	27
86	M24	Sgr	18h16.9m	−18°29'	SC	4.5	120x40
87	M18	Sgr	18h19.9m	−17°08'	OC	6.9	9
88	M25	Sgr	18h31.6m	−19°15'	OC	4.6	32
89	M17	Sgr	18h20.8m	−16°11'	DN	—	46x37
90	M16	Ser	18h18.8m	−13°47'	DN	—	35x28
91	M22	Sgr	18h36.4m	−23°54'	GC	5.1	24
92	M28	Sgr	18h24.5m	−24°52'	GC	6.9	11
93	M11	Sct	18h51.1m	−6°16'	OC	5.8	14
94	M26	Sct	18h45.2m	−9°24'	OC	8.0	15
95	M57	Lyr	18h53.6m	33°02'	PN	9.7*	1
96	M56	Lyr	19h16.6m	30°11'	GC	8.3	7
97	M39	Cyg	21h32.2m	48°26'	OC	4.6	32

Order #	Messier #	Con.	RA (2000.0)	Dec.	Type	Mag.	Size
98	M29	Cyg	20h23.9m	38°32'	OC	6.6	7
99	M27	Vul	19h59.6m	22°43'	PN	7.6*	6
100	M71	Sge	19h53.8m	18°47'	GC	8.3	7
101	M69	Sgr	18h31.4m	−32°21'	GC	7.7	7
102	M70	Sgr	18h43.2m	−32°18'	GC	8.1	8
103	M54	Sgr	18h55.1m	−30°29'	GC	7.7	9
104	M55	Sgr	19h40.0m	−30°58'	GC	7.0	19
105	M75	Sgr	20h06.1m	−21°55'	GC	8.6	6
106	M15	Peg	21h30.0m	12°10'	GC	6.4	12
107	M2	Aqr	21h33.5m	−0°49'	GC	6.5	13
108	M72	Aqr	20h53.5m	−12°32'	GC	9.4	6
109	M73	Aqr	20h59.0m	−12°38'	OC	8.9*	3
110	M30	Cap	21h40.4m	−23°11'	GC	7.5	11

Spiral Galaxy — M106

Jack Marling

After the telescope, your most important piece of equipment is a good star atlas. I find *Sky Atlas 2000.0* by Wil Tirion the best for running a marathon because each chart shows a wide slice of sky and stars down to magnitude 8.5, about the same as you'll see in an 8x50 finder. Most other atlases depict the sky in either too little or too much detail to help the marathoner home in on the Messier objects.

The sequential checklist plays a crucial role because it acts as your battle plan. It tells at a glance which objects you've seen and which you haven't, and the order in which you'll track them down. First you should decide how many objects to include in your list. Messier and Méchain catalogued 109 objects, but they made a few mistakes: M40 is a double star, M73 consists of just four stars, M91 is a spurious entry sometimes equated with NGC 4548, and M102 appears to have been a repetition of M101, though many people now accept it as NGC 5866. In addition some people designate NGC 205, a satellite galaxy to M31, as M110. So the marathon can consist of as few as 105 objects or as many as 110. I usually shoot for the maximum.

Develop your checklist well before the marathon. Start with bright evening objects like the Pleiades (M45) and the Orion Nebula (M42) that come into view long before the sky fully darkens. Next shoot for ones like M31 that lie low in the west and set soon after the Sun does. From there work your way across the sky from west to east, letting Earth's rotation bring new targets into view. Then end with objects like M73 that rise in the east shortly before sunrise. The table on pages 62-63 shows the order I've used for my past few marathons.

Race Day

Now you're all set for the big race. On the day of the event, arrive at your observing site well before sunset to set up your equipment and to make sure you haven't forgotten anything. Then check the telescope's collimation to be sure it will perform optimally.

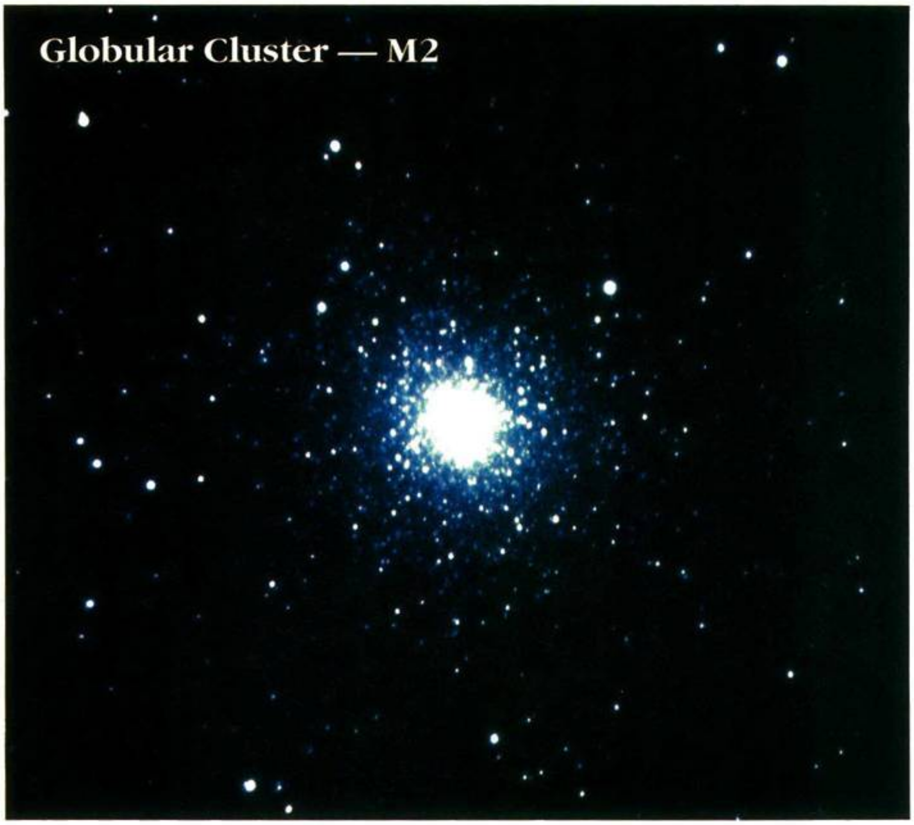
With everything ready, you can sit back and enjoy the sunset. Slowly, a few bright stars begin to peek out from the deep-blue sky. First Sirius, a brilliant blue-white beacon in the south. Then Rigel, Betelgeuse, Procyon, and Capella. Stars begin to fill the sky. The gun has been fired; the race is on.

It's essential to break from the starting line swiftly.

Hit the bright objects (numbers 1 to 5 on my list) while twilight still colors the sky, then hurry on to those that set shortly after dark (numbers 6 to 12): M31, M32, M33, M74, M77, M79, and M110. I give myself no more than five minutes to find each of them. If one remains hidden, I don't waste valuable time scouring the sky for it. Instead it's on to the next object, though I make a note to return later if time permits.

With the critical early evening objects behind me, I breathe a sigh of relief. I settle into a steady pace, conserving my energy for the long race ahead. Before long I've made it through the winter constellations, reveling, albeit briefly, at such wondrous sights as open clusters M41, M35, M37, and M46. All are dazzling, especially on a clear late-winter evening.

Before midnight the stars of spring replace those of winter, bringing forth a whole new family of Messier challenges. To the north lie the magnificent galaxies M51, M81, and M82, while to the south await Leo's remarkable M65, M66, M95, M96, and M105.



Bill Iburg

The attack begins slowly and deliberately but picks up speed at the Realm of Galaxies in Virgo and Coma Berenices. The Realm of Galaxies contains 13 Messier objects in a 30-square-degree area. To make things tougher, hundreds of fainter galaxies populate this region. Although Messier apparently missed these other galaxies, many lie within range of today's backyard telescopes. How can you tell which is which?

The key to navigating the Realm of Galaxies is a highly detailed chart. Unfortunately, *Sky Atlas 2000.0* isn't up to this challenge — the galaxies are crammed too closely together to be identified easily. (See the detailed finder on page 63 to maneuver through this crowded area.)

Remember this is a part of the race when you don't need to rush. Whatever path you choose for traversing the Realm, don't forget to pause and enjoy the many other galaxies along the way. Sure the Messier Marathon is a hectic event, but what fun is it without a few side trips for a little sightseeing?

Entering the Homestretch

After conquering the Realm, I breathe another sigh of relief. It's now about 2 a.m., and although the air is cold, I see the stars of summer rising in the east. The summer sky brings with it such deep-sky treasures as M8, M11, M13, M17, M22, and M57. The list of old friends, ones I haven't seen since last year, goes on and on. It's good to see them again, though I know the visit will be brief. Within two hours, dawn's first light will appear, eventually stealing back the night. I check off each object as I work from north to south along the Milky Way.

Entering Sagittarius, with the time just past 4 a.m., I catch the first hint of morning twilight. The marathon is now in the homestretch. Time to put on a final kick if I want to complete the Messier Marathon this night. I dive headlong into the critical early morning objects, pausing only briefly at M54, M69, and M70 along the bottom of the Teapot asterism in Sagittarius. Hurrying now, I seek M55 and M75, then speed on to M2 and M15.

As I get my second wind and chirping birds herald the coming dawn, I leap toward M72 and M73. "Where are they?," I wonder aloud. "I've got to find them." First the dim glow of the 9th-magnitude globular M72 comes into view. "Got it!" Then with steely determination, I turn toward M73. Dawn seems imminent as I lunge for the finish line on this, one of the poorest Messier objects. Then just as I am about to abandon the search, the four faint stars come into view. I've made it!

My checklist tells the tale — I saw 109 objects in the course of the night. The only Messier object that escaped was M30, an 8th-magnitude globular cluster in Capricornus. Unfortunately for observers north of 40° north latitude, M30 rises after morning twilight renders it invisible. But those who live farther south may glimpse it before the approaching dawn becomes too bright.

There's nothing in the world of amateur astronomy quite like the Messier Marathon. It's a once-in-a-year chance for backyard observers to cast off their otherwise placid demeanor and become true competitors. We don't compete against each other, however, but against ourselves. For like our counterparts on the marathon course, we aren't concerned with winning but with finishing the race. And trying to improve on our best efforts of the past.

Now on your mark, get set . . . □

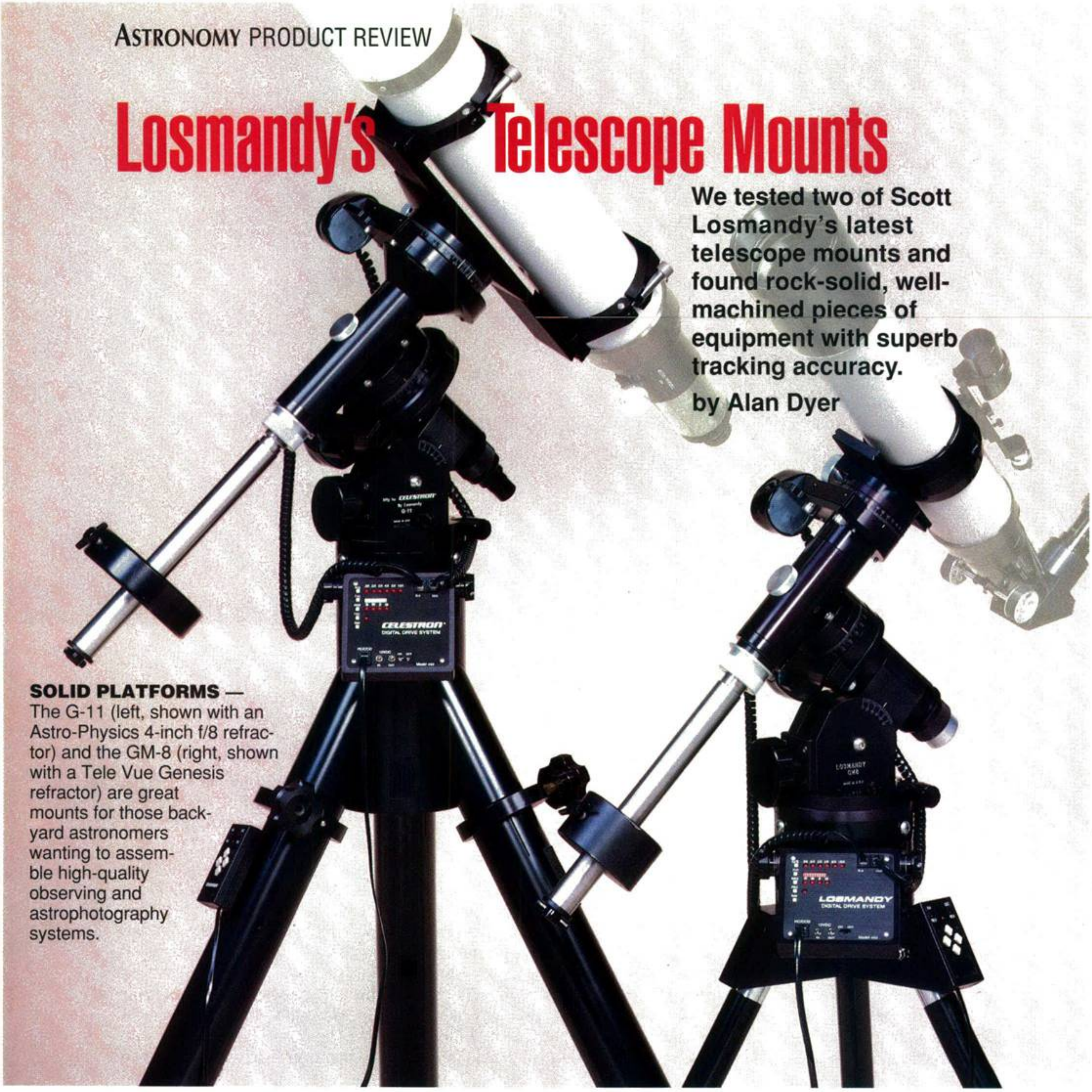
Phil Harrington is an avid deep-sky observer living in Smithtown, New York. His last article for ASTRONOMY *was "Tracking Down the Helix" (September 1992).*

ASTRONOMY PRODUCT REVIEW

Losmandy's Telescope Mounts

We tested two of Scott Losmandy's latest telescope mounts and found rock-solid, well-machined pieces of equipment with superb tracking accuracy.

by Alan Dyer



SOLID PLATFORMS — The G-11 (left, shown with an Astro-Physics 4-inch f/8 refractor) and the GM-8 (right, shown with a Tele Vue Genesis refractor) are great mounts for those backyard astronomers wanting to assemble high-quality observing and astrophotography systems.

ASTRONOMY: All equipment photos by Chris Becker

When selecting a telescope, most people choose an integrated system — optics and mount — from a single manufacturer. But some backyard astronomers prefer to pick an optical tube assembly from one manufacturer and place it on a mount of their own choosing. For the past few years, one of the leading *manufacturers* of premium telescope mounts has been Scott Losmandy and his company, Hollywood General Machining.

In 1992 Celestron International joined forces with Losmandy to produce the G-11 mount. But the G-11, a middleweight mount, is overkill for owners of small telescopes looking for a high-quality portable mount. To serve this market, in late 1993 Losmandy introduced the GM-8, a scaled-down version of the G-11.

I put both of Losmandy's latest products through their paces. Each proved to be a superb performer, offering everything essential in a top-quality mount — fast damping time, smooth tracking, easy polar alignment, a sophisticated drive system, versatile mounting hardware, all in a finely crafted package.

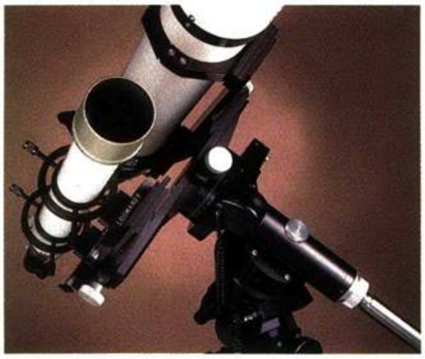
Mechanical Features

The G-11 and GM-8 are classic German equatorial mounts, a type of mount often preferred by astrophotographers because it is easy to balance. The bigger G-11 is for those wanting a mount capable of handling scopes up to 30 to 40 pounds. I placed 35-pound telescopes on the G-11 (a 6-inch f/8 refractor and a 7-inch Maksutov, for example) and found it handled such a load quite well. As long as the mount was balanced, damping time was a fast 1 to 1½ seconds. If the mount was out of balance, damping time could be as high as 5 seconds with heavy loads. I felt that a 35-pound load approached the G-11's limit for demanding applications such as astrophotography. A lighter load, such as a 15- to 20-pound 5-inch refractor with a small guidescope, would be an ideal combination for astrophotography with the G-11. The 11-inch Schmidt-Cassegrain that Celestron currently packages with the G-11 also works well with this mount.

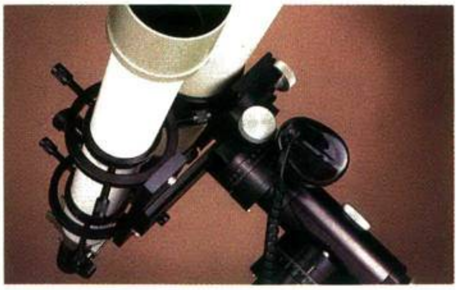
The smaller GM-8 is ideal for an 8-inch Schmidt-Cassegrain, a fast 6-inch Newtonian, or a 4-inch or lightweight 5-inch refractor. I used it in conjunction with an 11-pound Tele Vue Genesis, a 4-inch f/5.4 refractor (see "Tele Vue's Genesis SDF," January 1994). The two dealers with the rights to market the small Losmandy mount, Pocono Mountain Optics and Spectra Astro-Systems, are currently packaging the GM-8 with the Genesis for those wanting an equatorial mount for this versatile telescope. I found that the Losmandy/Genesis marriage was an ideal match. With the Genesis, damping time of the GM-8 was a mere one second, as good as I've seen on any mount. An 8-inch Schmidt-Cassegrain tube assembly placed on the GM-8 would provide a similar solid combination.

Another critical specification in a premium mount, at least for astrophotographers, is tracking error. A mount that drifts back and forth due to poor mechanical tolerances in the drive system will be difficult to guide. The G-11 showed a mere 10 arcseconds of periodic error over a four-minute cycle (the rotation period of the worm gear), among the lowest I've seen in any premium mount. The GM-8 exhibited 20 arcseconds of periodic error over an eight-minute cycle, a superb figure that is as good as or better than any other mount in its class. Most important, the periodic error in both mounts consisted of a gradual drift that was easy to guide out. Both mounts should be fine for taking snapshot images with CCD cameras in an unguided "track-and-accumulate" mode.

Precise tracking is for naught if the mount is not polar-aligned accurately. The GM-8 and G-11 use the same polar alignment scope, which screws into the polar axis. The mounts also share the same base, with identical adjustments for altitude and azimuth. These adjustments were easy to use and made zeroing in on the pole a snap. The polar scope's reticle of alignment lines proved to be deadly accurate. Placing Polaris in the right spot on the illuminated reticle each night typically took only 30 seconds. Yet during 30-minute exposures the mounts required virtually no guiding corrections in declination, even guiding at over 200x, proof the mounts were precisely polar aligned. (The reticle also works in the Southern Hemisphere.)



THE G-11 can be outfitted for astrophotography using a system of interlocking dovetail plates. A side-by-side plate first clamps to the top of the mount. One side holds a dovetail plate to which you attach the main telescope. The other side holds a second plate to which you can clamp adjustable guidescope rings (shown) or piggyback mounts.



THE SMALLER GM-8 can be outfitted for astrophotography with a similar but scaled-down arrangement. A small side-by-side adapter holds the main scope in a dovetail bracket, while a second small plate holds a pair of rings for a guidescope.

My only quibble with the polar alignment scope is that the illuminator's LED is dim, making it hard to see the full reticle pattern, and it is powered by a separate battery pack that dangled awkwardly from the back of the mount. Some sort of connector to power the illuminator from the control panel's 12-volt output jack would be better.

Both mounts feature finely engraved setting circles. The declination circles are graduated in 2° increments, the right ascension (RA) circles in 6-minute increments. There are no vernier scales, making precise settings with the circles difficult. The RA circles on both mounts are driven so users of setting circles need only calibrate the RA circle once at the beginning of the night. Both mounts have tapped holes on each axis for adding optical encoders used by digital setting circles.

The RA and declination locks consist of clutched rings on the end of each axis that you turn to clamp the mount tight. These worked well — you can leave the locks on with enough tension to hold the scope and still swing the mount around the sky. But the knurled rings were not as convenient to use as the levers employed on some other mounts. For example, twisting the lock rings could sometimes rotate the axis, causing you to lose your target just as you're trying to lock onto it. With a long, heavy scope (a 35-pound refractor) attached to the G-11, I found the declination axis would not lock down as tightly as I'd like. The scope would be held firmly but it didn't take much force to swing the mount off target, a worry for astrophotography. For lighter, shorter scopes that exerted less torque on the mount, this was not a problem.

Another proviso is that with the G-11, you cannot look eastward when the telescope is on the east side of the tripod — the top of the mount hits the RA motor housing if you try to swing the scope east past the meridian. This isn't much of a concern since, when looking east with a German equatorial mount, the scope should be on the west side of the mount anyway. The GM-8 has no such restriction.

Both mounts follow a similar design — a head that bolts to a cylindrical semipier that has three legs attached to it. With the GM-8 the fold-up legs come bolted to the pier and have small rubberized feet that can screw up or down over a one-inch height range for leveling the tripod. The much larger legs of the G-11 clamp onto the pier's three pipelike extensions. The G-11 can

LOSMANDY MOUNTS

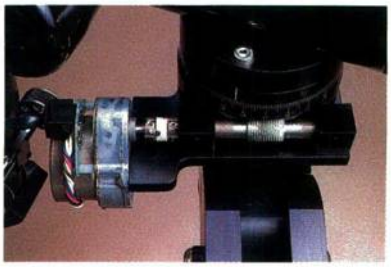
Standard specifications	**Celestron G-11**	**Losmandy GM-8**
Estimated carrying capacity	25 to 40 lb	15 to 25 lb
Recommended scopes	up to: 11-inch SCT 6-inch f/8 refractor 10-inch f/6 reflector	up to: 8-inch SCT 5-inch f/8 refractor 6-inch f/6 reflector
Weight of head	31 lb	20 lb
Weight of tripod and semipier	20 lb	16 lb
Measured tracking error	10 arcseconds	20 arcseconds
Measured damping time	1.5 seconds	1 second
Suggested list price	$3,258	$2,700
Typical price (with drives, polar scope)	$2,000	$1,350
Optional accessories		
Side-by-side mounting bracket	$320 (7 lb)	$84 (2.5 lb)
Genesis mounting plate	$100 (2 lb)	$49 (0.7 lb)
C8/Meade 8 mounting plate	$120 (2 lb)	$49 (0.7 lb)
Astro-Physics mounting plate	$120 (2 lb)	—
90mm rings (pair)	$150 (2 lb)	$69 (0.6 lb)
125mm rings (pair)	$200 (2.2 lb)	—
177mm rings (pair)	$280 (3 lb)	—
Dovetail plate adapter (for your own rings)	$50 (0.6 lb)	—
Male-to-male dovetail plate	$70 (3.3 lb)	—
Single-axis piggyback mount	$100 (1.1 lb)	—
Dual-axis piggyback mount	$150 (2 lb)	—

Also available directly from Hollywood General Machining: Large GM-200 mount, finderscope brackets, counterweight, and accessory systems for Schmidt-Cassegrains.

Hollywood General Machining, 1033 N. Sycamore, Los Angeles, CA 90038, (213) 462-2855.
Model G-11 sold through Celestron International, 2835 Columbia Street, Torrance, CA 90503, (310) 328-9560 and through Celestron dealers.
Model GM-8 sold through Pocono Mountain Optics, RR 6, Box 6329, North Pocono Village Shopping Center, Moscow, PA 18444, (717) 842-1500 and Spectra Astro-Systems, 6631 Wilbur Avenue, Suite 30, Reseda, CA 91335, (800) 735-1352.

Side-by-side dovetail plate (slides into channel on mount)

THE POLAR ALIGNMENT ADJUSTMENTS of both mounts are identical and provide a precise means to zero in on the celestial pole. Two knobs on either side of the gold post shift the mount east-west. The large knob shifts the head up and down.



BOTH MOUNTS USE WORM GEAR DRIVES for right ascension and declination. The GM-8 (shown) uses 2.8-inch-diameter driving gears, while the bigger G-11 uses 5.6-inch-diameter gears for better tracking accuracy.

LOSMANDY
DIGITAL DRIVE SYSTEM

THE SAME CONTROL PANEL and hand controller box are used on both mounts. The electronics offer four tracking speeds, six guiding and slewing rates, periodic error correction circuitry, and inputs for CCD autoguiders and 12-volt power supplies.

then be leveled by sliding the legs up and down these extensions, although leveling this or any other mount isn't required for polar alignment. The G-11 comes with 48-inch-high legs as standard equipment. Also available are 26-inch legs for use with Newtonian scopes and 60-inch legs for use with long-focus refractors.

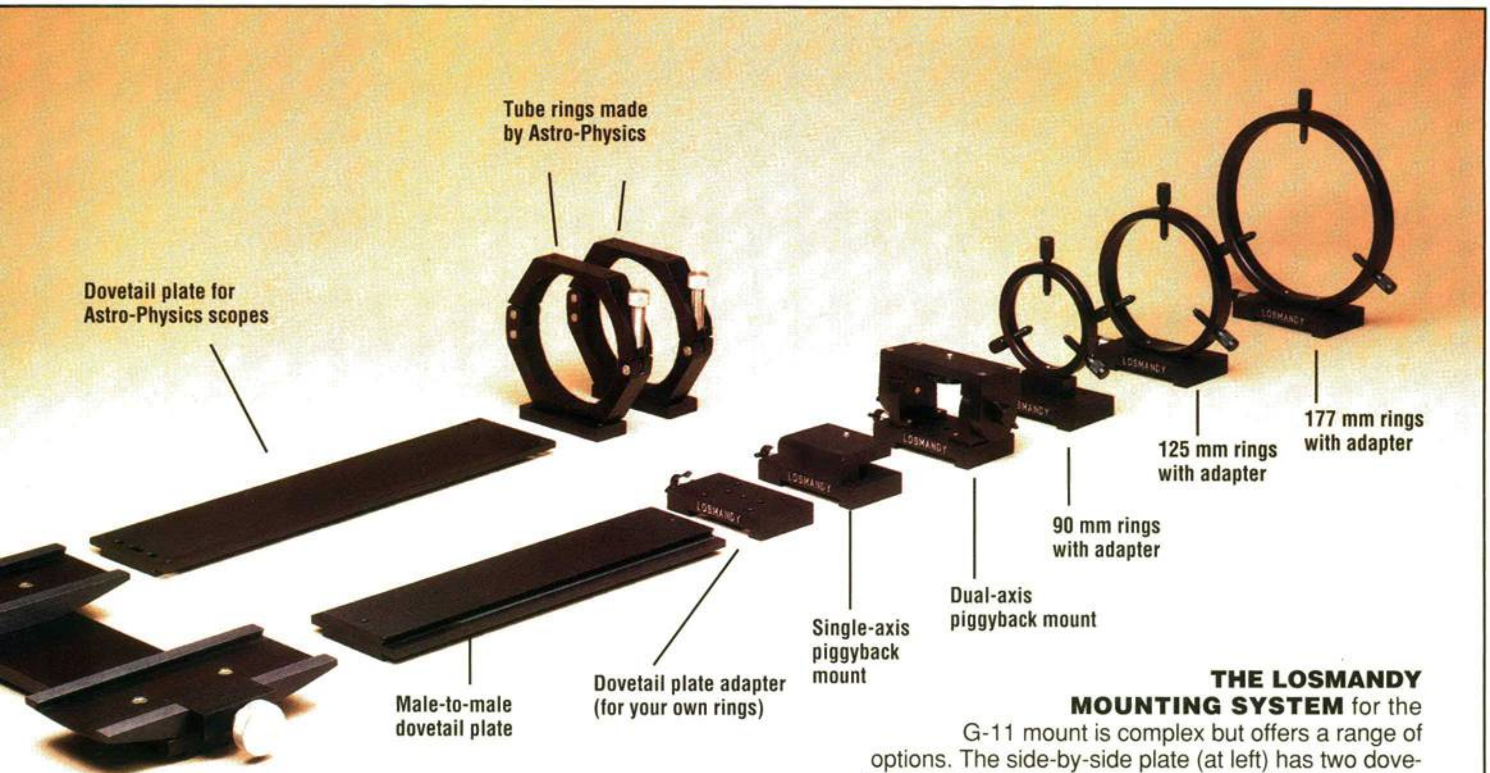
The heads of the GM-8 and G-11 are beautifully machined and black anodized. The piers, legs, and counterweights, however, are painted. Losmandy is now using more durable paints than he did on the first G-11 mounts whose painted parts tended to blister and chip easily.

The GM-8's 7-pound counterweight balanced the Genesis nicely but was not heavy enough to balance a Genesis-plus-60mm guidescope setup. GM-8 buyers have the option of substituting an 11-pound counterweight supplied with the G-11.

Electronic Features

The GM-8 is available with manual slow-motion controls on both axes. These operated very smoothly but must be removed if you attach the optional dual-axis drive motors. With motors in place on either the GM-8 or G-11, you must use the electric drives to make fine pointing adjustments. This does make you dependent on electric power, but the control panel offers an excellent range of speeds.

You can select from six speeds, marked as 0.3x, 0.5x, 2x, 4x, 8x, and 16x. The fastest, 16x, lets you center on an object while the slowest, 0.3x, enables you to guide on the object. The 0.3x speed moves the mount at roughly 3 arcseconds per second, the 0.5x speed at about 7 arcseconds per second. Both are wonderful for


Tube rings made by Astro-Physics
Dovetail plate for Astro-Physics scopes
177 mm rings with adapter
125 mm rings with adapter
90 mm rings with adapter
Dual-axis piggyback mount
Single-axis piggyback mount
Dovetail plate adapter (for your own rings)
Male-to-male dovetail plate

THE LOSMANDY MOUNTING SYSTEM for the G-11 mount is complex but offers a range of options. The side-by-side plate (at left) has two dovetail channels into which you can slide mounting plates to suit various telescopes. The standard plate (at top) accepts mounting rings from manufacturers such as Astro-Physics (shown). The male-to-male plate (bottom) offers a dovetail channel onto which you can clamp a selection of Losmandy piggyback mounts and tube rings.

precise guiding. I found these much more accurate than the usual 2x guiding speed (15 arcseconds per second) included on these and most other mounts. Even better, the drives moved at the same rate in both RA and declination, a great aid to manual guiding and a desirable feature for CCD autoguiders.

With the G-11 you can turn on the 16x slewing speed at any time by pressing two of the hand controller's buttons at once, a convenient feature. With the GM-8 this technique triggers a 32x slewing speed. The only catch to using the slewing speeds is that they do drain batteries. Both mounts will work off any 12-volt source but if the voltage drops much below that, the high speeds give out (although the RA drive itself continues to run).

The control panel on both mounts offers a choice of four tracking speeds: solar, lunar, sidereal, and the King rate, a variation on the sidereal rate that compensates for atmospheric refraction. The drives also have periodic error correction, or PEC. When activated, this circuit memorizes drive corrections you make in RA and plays them back after four or eight minutes (the period of the worm gear). I tried the PEC but quite frankly I found it superfluous. The tracking was already so smooth that recording my corrections probably introduced more random variations than I was guiding out.

The Losmandy drive system also offers a circuit called TVC for Time Variable Constant. This neat feature takes out backlash in declination by speeding up the dec motor momentarily when you reverse directions. With it set, the declination motor responded instantly, moving in either direction. Without TVC, the G-11 hesitated with two seconds of backlash at 0.5x speed; the GM-8 had six seconds of backlash at the same speed.

The only glitch I found in the drive system was in the G-11. When observing at high power, I sometimes noticed a high-speed east-west jitter in images of about one arcsecond. At first I thought I was seeing the inherent stepping of the pulse motor. But Losmandy diagnosed it as a resonant vibration in the RA axis. Throwing the mount slightly out of balance in RA eliminated the jitter. A thin rubber gasket added between the RA motor and the mount also solved the problem.

The Losmandy System

The G-11 and GM-8 mounts form the core of Losmandy's system of mounting accessories. Visual observers can attach a telescope to the top of the GM-8 using a small dovetail bar. Or astrophotographers can attach an accessory plate that in turn holds a dovetail-mounted scope alongside a small ring-mounted guidescope. Switching back and forth between the two arrangements takes only seconds.

The heavier G-11 offers a wider range of options. It uses a system of hefty dovetail plates (not compatible with the GM-8) to mount telescopes, guidescopes, and piggybacked cameras. These clamped securely with no slop or flexure.

The black-anodized plates are heavy, however. The combination of plates and mounting rings needed to secure a refractor alongside a guidescope weighed over 14 pounds (not including the telescopes themselves), something to consider when assembling a system.

The Losmandy accessories are well engineered and beautifully crafted. Together with the G-11 and GM-8 mounts, they provide a versatile yet rock-solid mounting system that provides a fine match for many of today's high-performance telescopes. ☐

VIRTUAL SKY

If it comes at you out of a computer screen instead of an eyepiece, is it still astronomy? The electronic heavens can offer viewing just as beautiful as the real thing — and a lot more comfortable.

by Robert Burnham

Electronic imaging can change your whole outlook on astronomy. For one thing, it lets you see things from a suburban backyard that you'd ordinarily need dark skies to see. A CCD camera can reach up into a sky glowing with light pollution and pull down images of galaxies and nebulae. It can do this because it allows you extraordinary control over the image. Got a galaxy only a couple percent brighter than your local sky? No problem. Just process the image to suppress the bright sky background and let the galaxy shine forth.

CCD imaging also brings astrophotography into the reach of many who would rather not fuss with hypersensitizing, cold cameras, autoguiders, and all the arcana that surround conventional astrophotography, film processing, and print making. Plus you do it at the computer in a comfortable study and not in some basement or utility room where all the spiders wish you would please go away.

M61

Many would-be electronic astrophotographers assume you need a large telescope and a huge mounting with motorized axes to do CCD imaging. It's true that a home observatory makes the process easier, but it's by no means necessary, especially when you begin. CCD cameras are light, typically weighing much less than an SLR body. The fact is, you can get satisfying results with small telescopes on medium-sized mountings using an ordinary clock drive. Moreover, unless you're keen on imaging small things — planets, some nebulae, or small galaxies — you won't want the enormous image scale that a

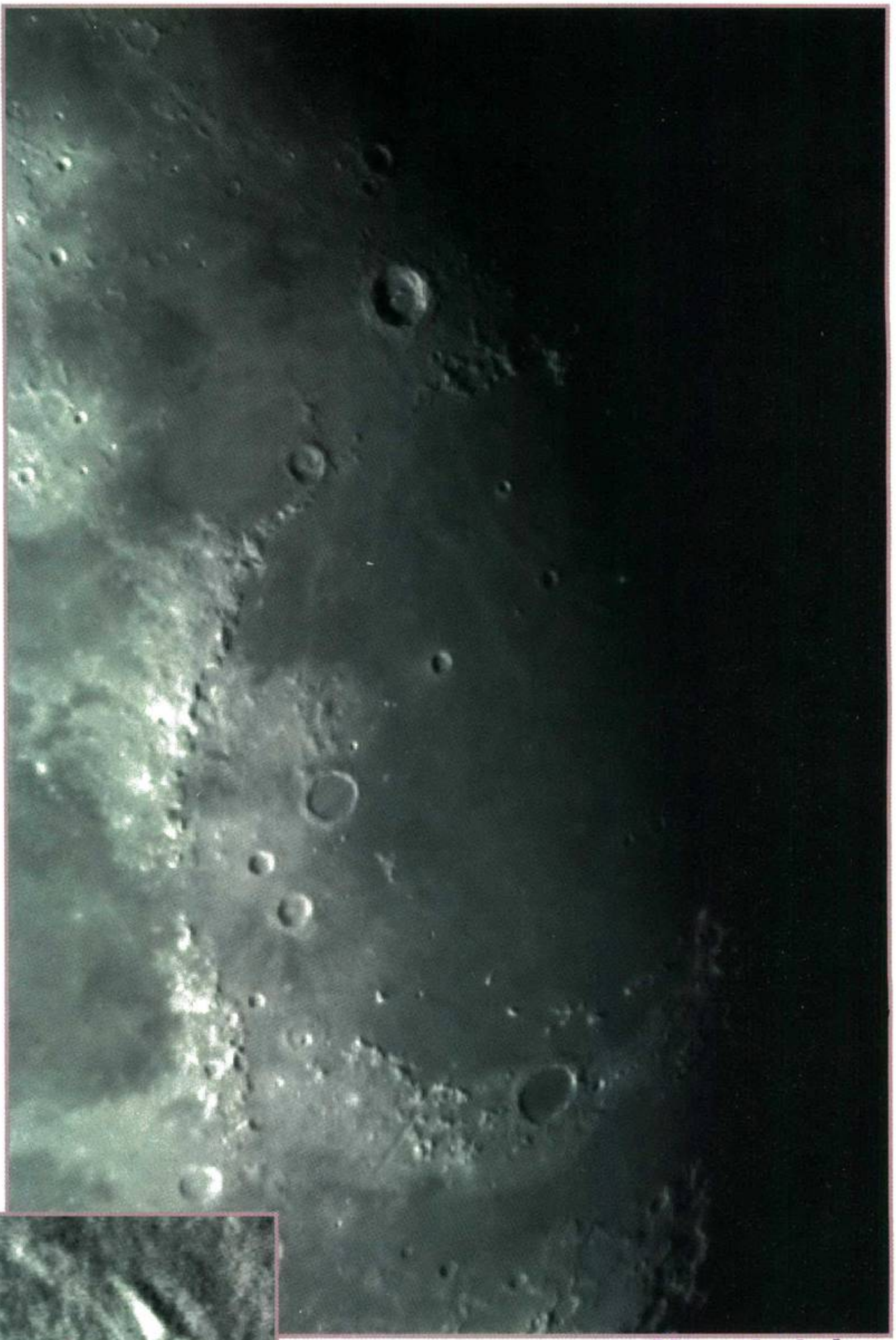
(continued on page 77)

A celestial chesspiece, the **Horsehead Nebula** in Orion is notoriously difficult to see, but Ian King and Nik Szymanec took its portrait easily. Keith Snyder photographed the **Great Galaxy in Triangulum** while Jack Newton snapped galaxy **M61** in Virgo and emission nebula **NGC 7538** in Cepheus.

Horsehead Nebula

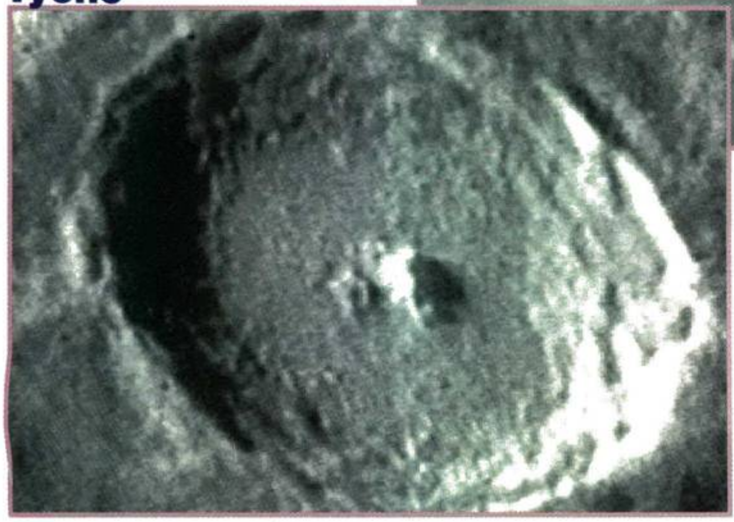
The Great Galaxy in Triangulum

NGC 7538

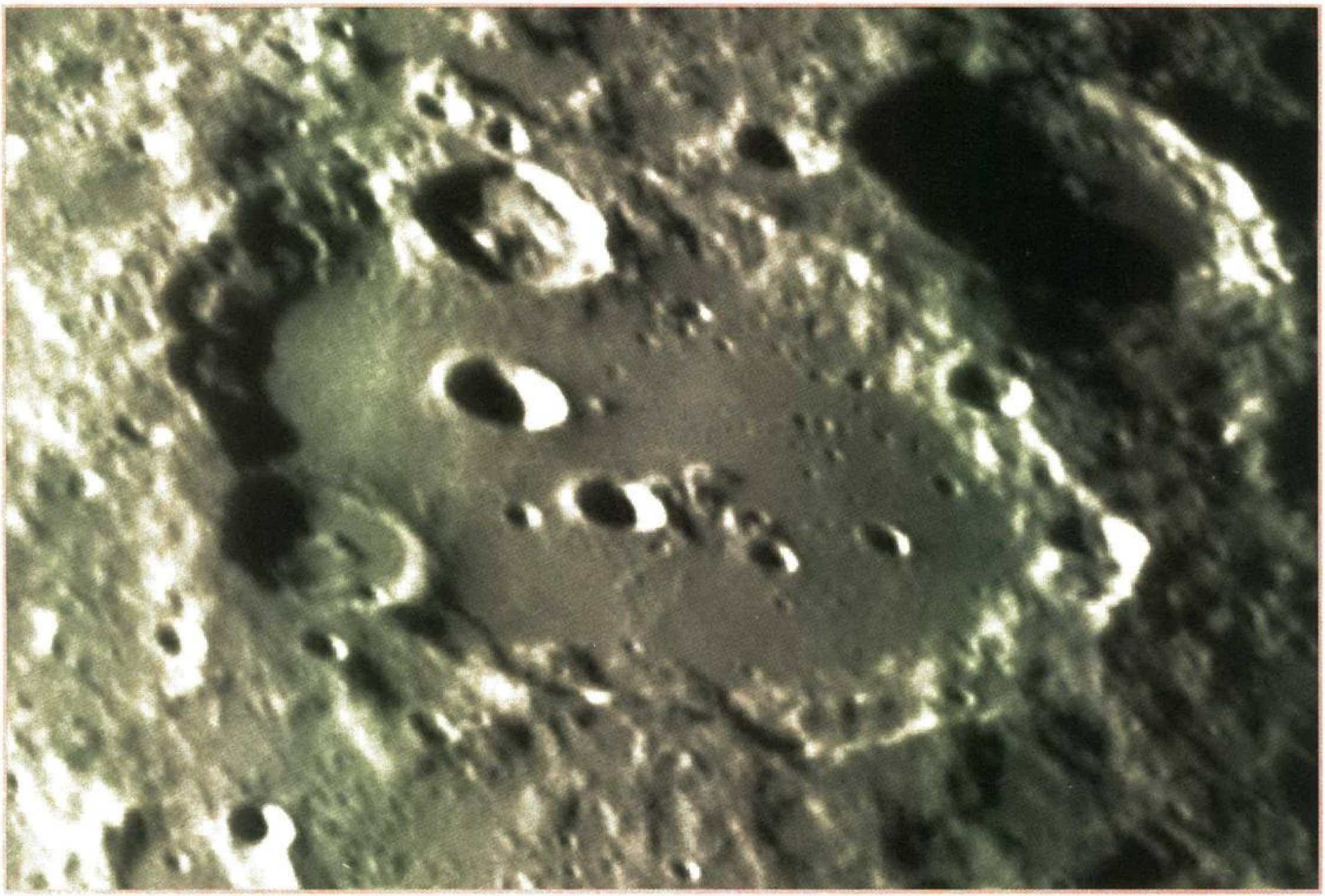


Mare Imbrium

Tycho

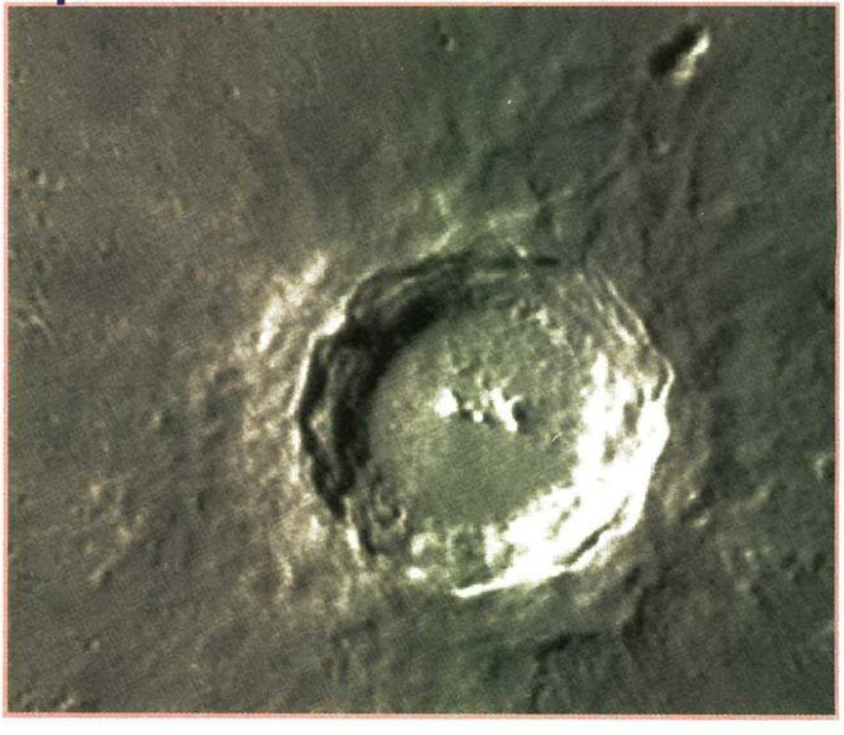


Craters big and little. James Edlin imaged the tangled region around **Copernicus,** the landslides inside **Tycho**, and the convex-floored **Clavius**. The fractured interior of **Gassendi** caught Greg Terrance's interest, while George Fowler aimed wide to take in huge swaths of **Mare Imbrium**.

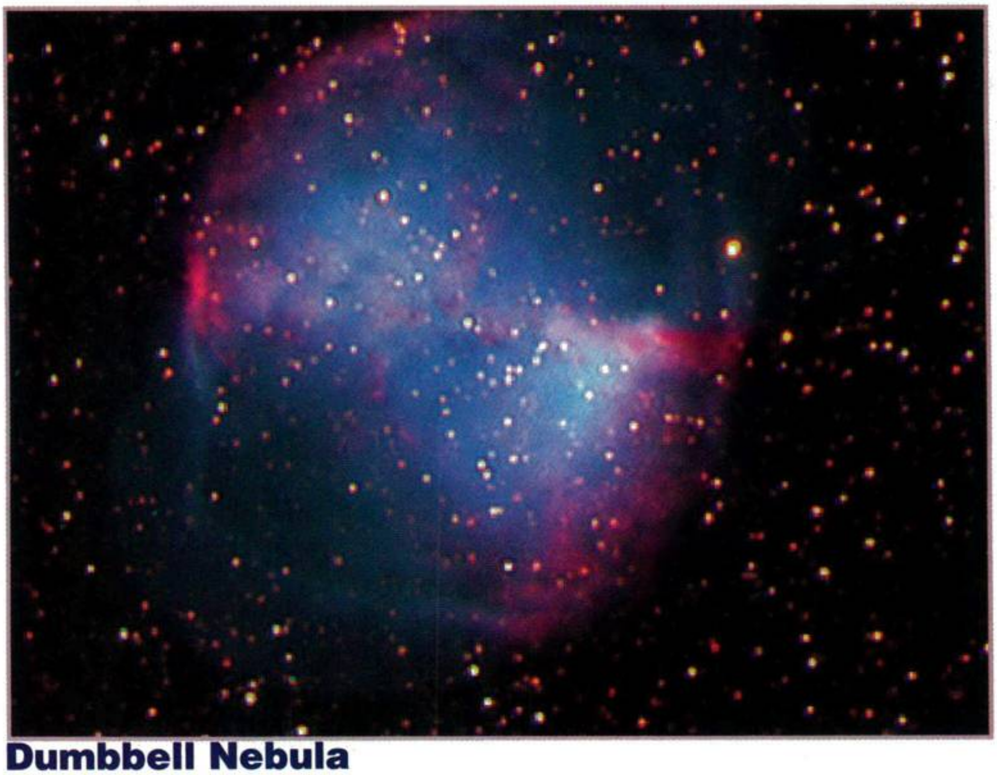


Clavius

Copernicus

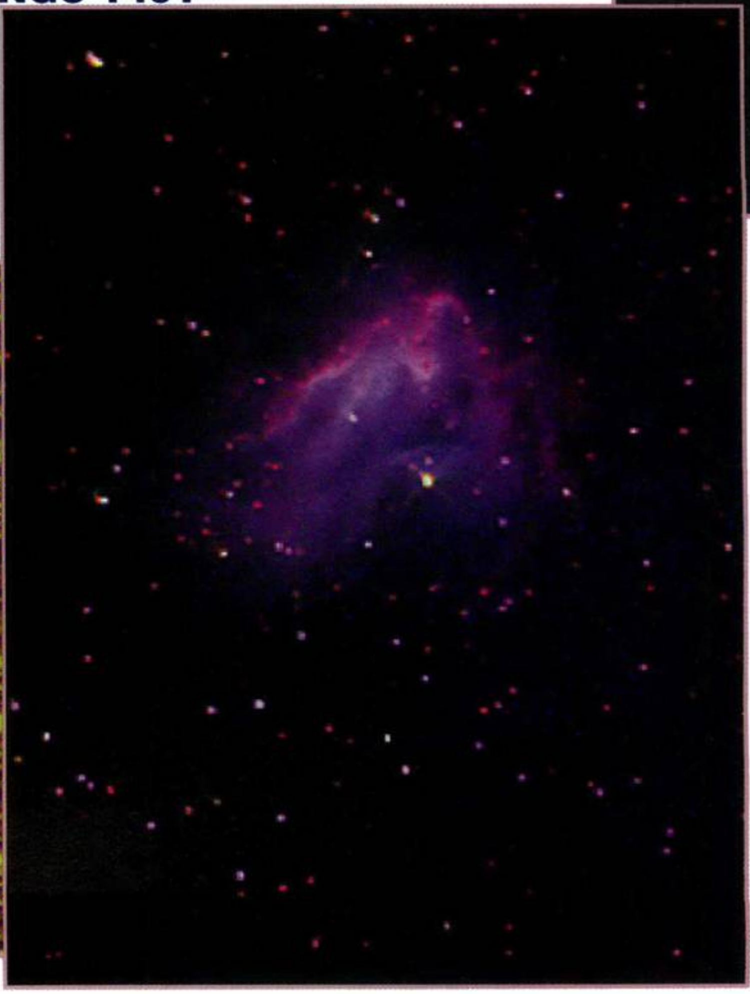


Gassendi

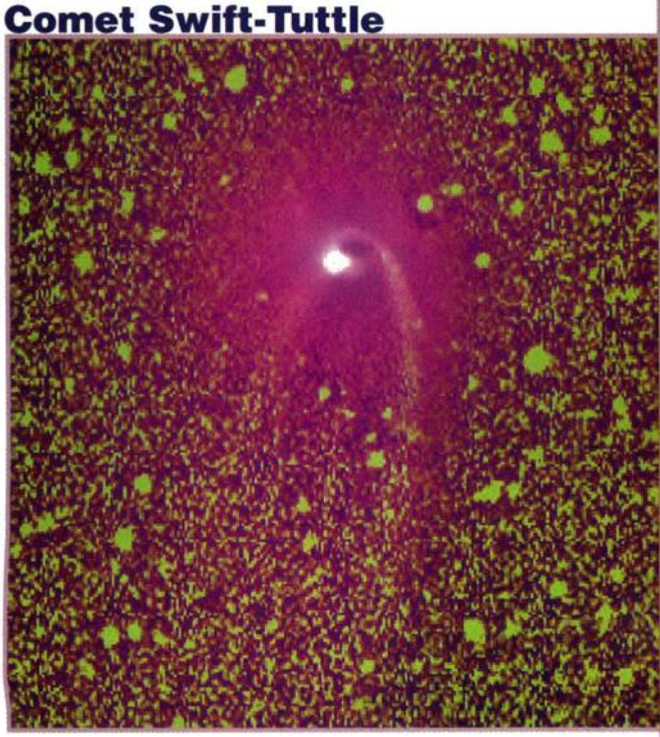


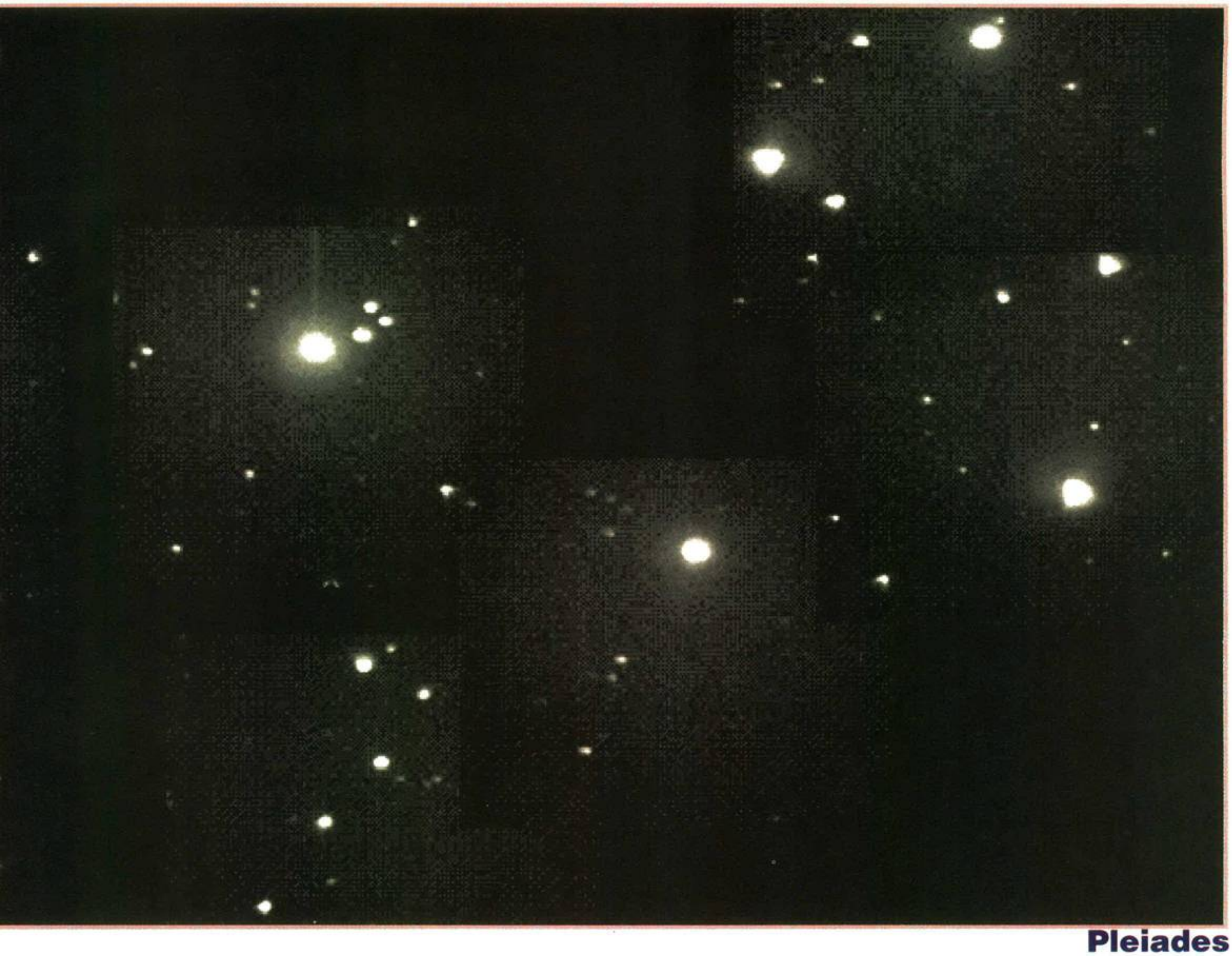
Dumbbell Nebula

NGC 1491



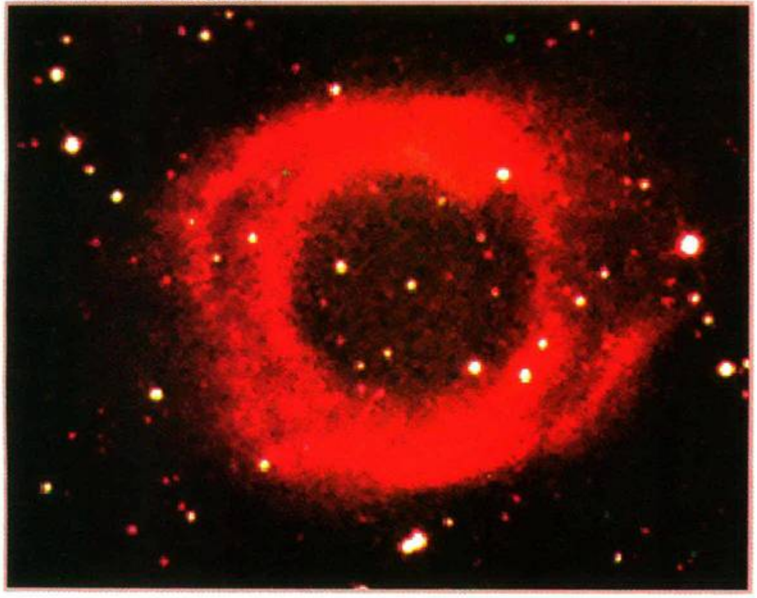
Comet Swift-Tuttle



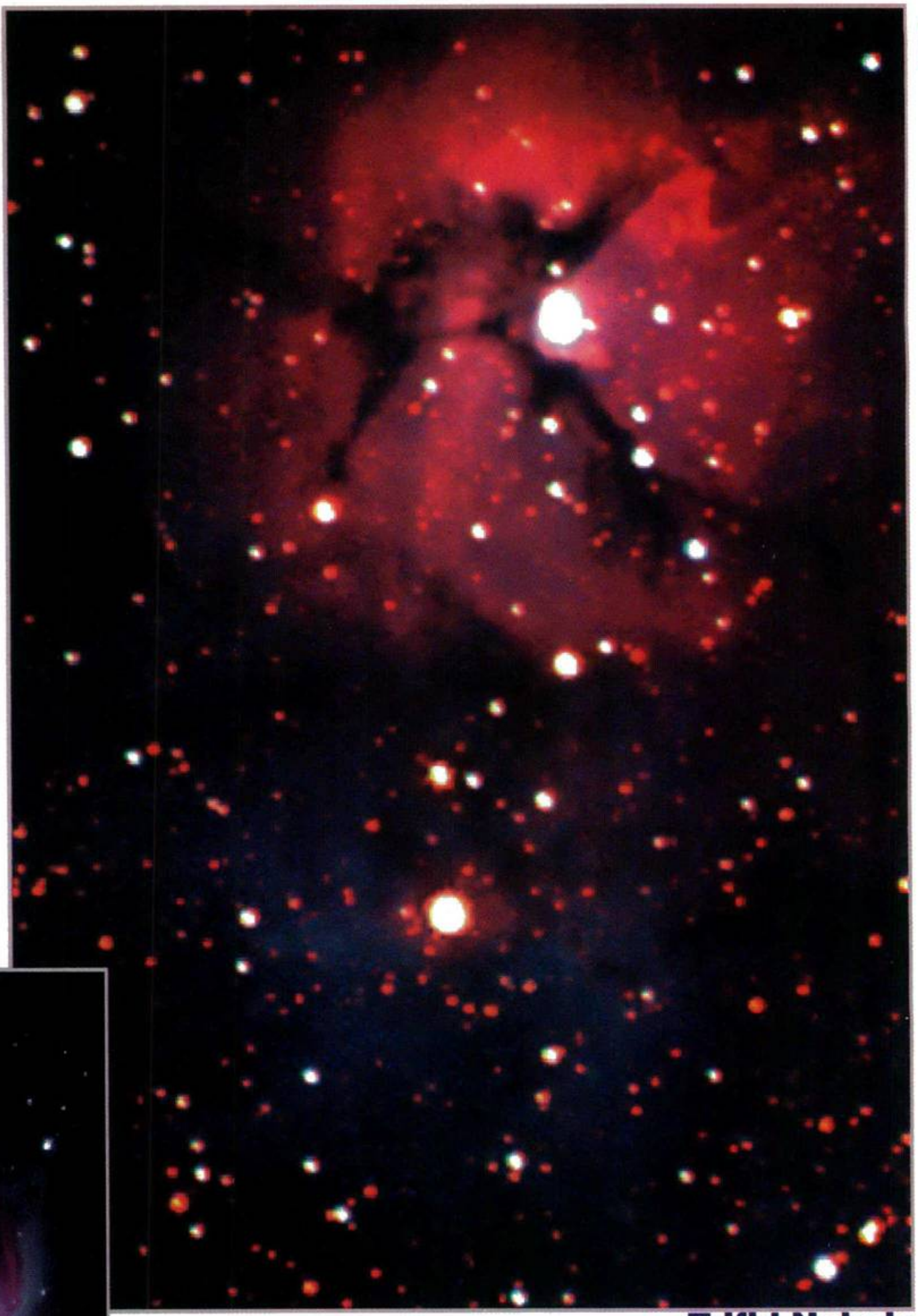


Pleiades

Helix Nebula



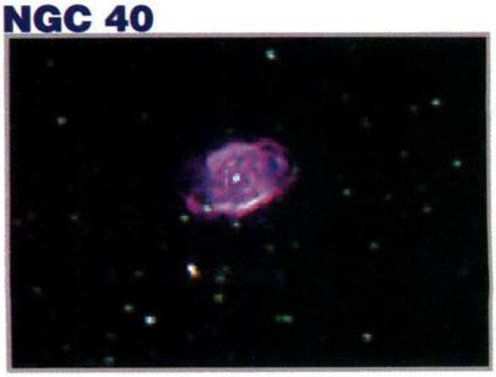
Whirling jets of gas shoot from the nucleus of **Comet Swift-Tuttle**, photographed by Jack Newton in December 1992. Michael Borman found the **Pleiades** cluster in Taurus much too large for one frame, so he took the cluster apart. Jack Newton caught **NGC 1491**, a small, bright nebula in Perseus. The linked circles of the **Helix Nebula** in Aquarius glow red, while the soft light of the **Dumbbell Nebula** (M27) shines in Vulpecula. Photos by Keith Snyder, Steve Messner, and Bob Elliot (Helix) and Jack Newton (Dumbbell).



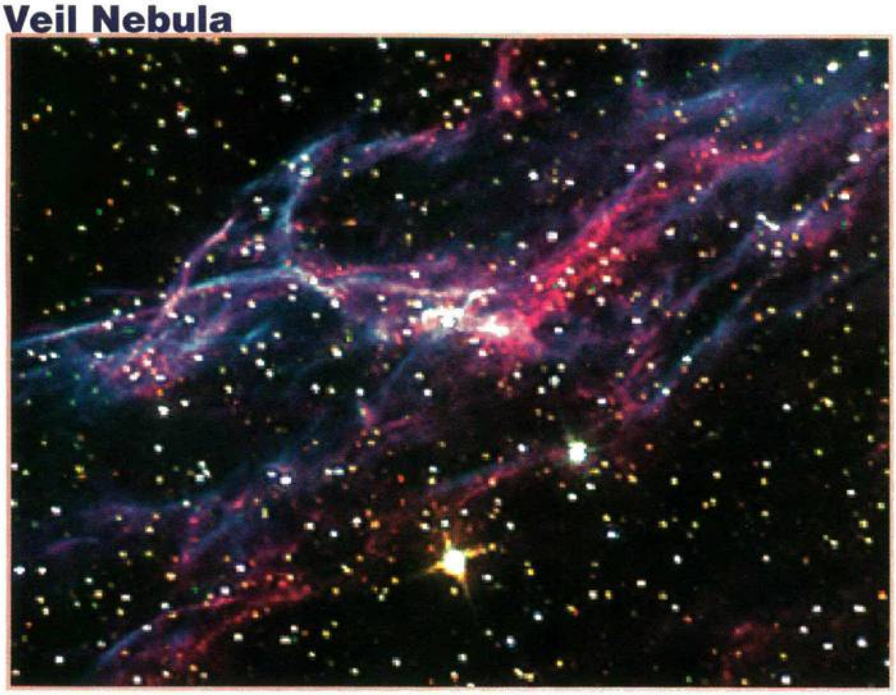
Trifid Nebula

Orion Nebula

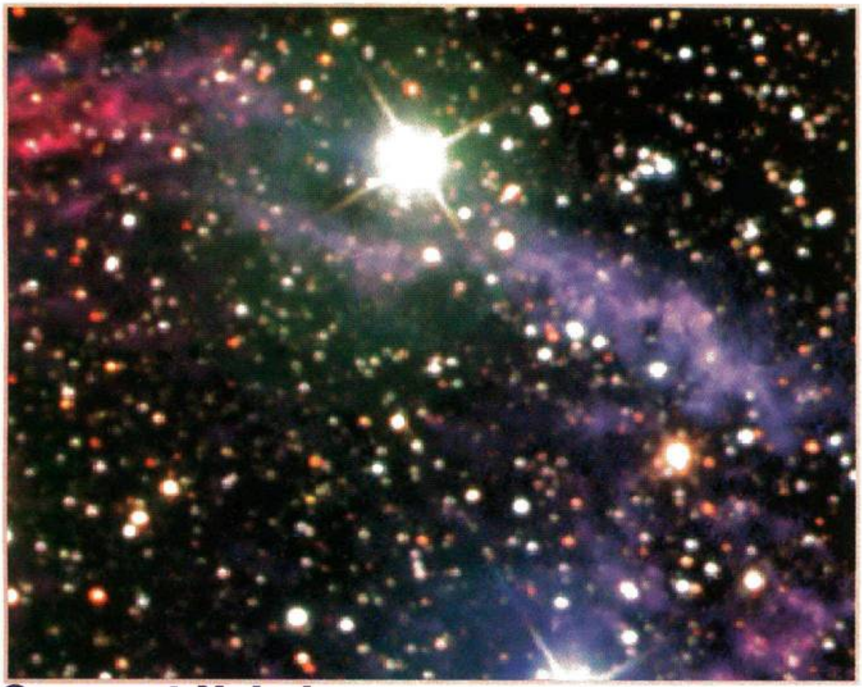
NGC 40



Veil Nebula



Filmy strands of star-stuff make up the **Veil Nebula** in Cygnus, an old supernova remnant. The **Trifid Nebula** (M20) in Sagittarius got its name from the dark lanes of dust dividing it. The great **Orion Nebula** (M42) is easy to see but its outer "petals" of light are hard to capture. Planetary nebulae like **NGC 40** in Cepheus are the shells of gas ejected by aging stars. The **Crescent Nebula** (NGC 6888) lies amidst the stars of the summer Milky Way in Cygnus. Photos by Ian King and Nik Szymanec (M42) and Jack Newton.



Crescent Nebula

telescope provides when used as the lens of a CCD camera. Remember that CCD chips are only about 1/10th of an inch on a side. This means ordinary telephoto lenses grab good views of celestial objects. You save the main telescope for those tiny targets that demand an appropriately large image scale.

What can you do with a CCD? Beyond the obvious taking of beautiful pictures for personal satisfaction, CCDs are tools for exploration. They're interactive. You can literally play with an image endlessly. For example, you can measure the brightnesses of variable stars, find matter at the outer reaches of galaxies and nebulae, and probe the structure of jets coming from the nucleus of a comet. Conventional film can do most of these also — but not as well or as easily. That's the key difference.

Because CCD imaging provides a new way to look at the sky, it gives you a new "take" on enjoying astronomy. For astrophotographers, the new medium also offers fresh fields to conquer. And for the many others with a computer but no home darkroom — well, you're halfway there already.

And besides, it's just a lot of fun. □

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**Plossl test, "SKY & TELESCOPE," p490-492, May 1988*

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12'' LX200 $3995

NEW Meade 8'' LX200 Telescopes

See the Meade ad in this magazine for full specifications & details. **LX100 Drive**, 2X, 32X speed control with PPEC (Permanent Periodic Error Correction "Smart Drive") & dual-axis hand controller. **LX200 Drive**, Full electronic control with PPEC, 747 object computer memory and automatic computer controlled slewing to desired object. *NOTE:* A wedge is **not** needed for visual observing with the LX200 Drive. Select f/10 or f/6.3 (no extra charge) for your Schmidt-Cassegrain.

8'' LX100 Schmidt-Cassegrain with wedge (add $105 P&S)	**$1995**
8'' LX200 Schmidt-Cassegrain with computer (add $105 P&S)	**$2295**
Wedge for photographing with 8'' LX200	**$110**
10'' LX100 Schmidt-Cassegrain w/super wedge (add $145 P&S)	**$2895**
10'' LX200 Schmidt-Cassegrain with computer (add $145 P&S)	**$2895**
NEW! 12'' LX200 (f/10 only) with computer (add $215 P&S)	**$3995**
Super Wedge for photography with 10'' or 12'' LX200	**$395**
8,000 Object CNGC Library (Version 2.5 software)	**$99**
Library Option 1: 10,600 NGC, Messier, IC objects (Ver. 3.2 only)	**$99**
Library Option 2: 64,350 celestial objects (Version 3.2 only)	**$149**

OTHER SCHMIDT-CASSEGRAINS

Meade 2045D 4'' f/10 with motor drive (add $40 P&S)	**$699**
Meade 2080B 8'' f/10 with tripod, wedge, MCOG (add $85 P&S)	**$1149**
NEW! Model 2120B 10'' f/10 w/wedge, tripod, MCOG (add $125)	**$1449**

PHOTOGRAPHY ACCESSORIES

LUMICON Cassegrain EASY-GUIDER 4'', 8'' only, f/6 or f/10	**$225**
LUMICON Giant EASY-GUIDER for 10'' or 12'' f/4-f/10 operation	**$395**

MEADE STARFINDERS

8'' f/6 $699*

New 8'' f/6 Meade Starfinder telescopes

See the Meade ad in this magazine for full descriptions and technical specifications for 6'' to 16'' Starfinders. These are complete telescope systems with motor drive, mount, finderscope and 25mm (=48X) eyepiece.

6'' f/8 Starfinder 6(add $50 P&S)	**$599**
8'' f/6 Starfinder 8 (add $60 P&S)	**$699**
10'' f/4.5 Starfinder 10 (add $75 P&S)	**$799**
16'' f/4.5 Starfinder 16 (ship. freight COD)	**$2195**

*All Starfinder telescopes shipped directly from Meade to the purchaser. Please add the indicated shipping charge to the price. LUMICON showroom prices are $96 higher.

ACCESSORIES

LUMICON carries the full line of Meade accessories. See the Meade ad in this magazine for detailed prices and descriptions.

LUMICON Single axis drive corrector	**$99**
LUMICON DX200 Dual-axis drive cor.	**$249**
Meade 47M Dual-axis drive corrector	**$450**
LUMICON DX2BP Dual-axis drive corrector with built-in battery pack	**$299**

LUMICON® SKY VECTOR™

Higher Performance — Lower Price

LUMICON ACCESSORIES

LUMICON, 2111 Research Dr., #5, Livermore, CA 94550 (510) 447-9570 FAX (510) 447-9589

LOW PRICE—from $399

LUMICON SKY VECTOR FEATURES:

- "GUIDE" mode leads you to object
- Digital right ascension readout to 1 min.
- Digital decl. readout to 10 arc-min.
- 4000 pulse (0.09° accuracy) encoders
- Polar alignment ***not required!***
- Motor drive ***not required!***
- Just sight two stars to align!
- Works **equally well** for alt-azimuth telescopes like Coulter Odyssey and equatorial mounts like C-8, Meade 2080.
- **No need** to enter latitude, longitude, etc.

SKY VECTOR I™ $399

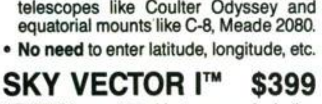
NEW! With over 220 object memory including the 110 Messier and 58 best NGC objects.

SKY VECTOR II™ $499

IMPROVED — Planets, Over 3,700 Objects! With size, magnitude and full visual description.

NGC SKY VECTOR™ $699

IMPROVED!—5500 Additions / Corrections

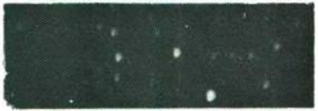


Improved NGC SKY VECTOR with over 12,000 object memory including the planets, complete, corrected RNGC catalogue, IC catalogue, P&K planetary catalogue, & much more!

Specify Telescope Type: Meade 2045, 2080, 2120, C-8, C-11, Odyssey 8, 10, 13, 17½, Alt-Azimuth.

Ultima 8, 11 .. **add $25**, C-14 .. **add $75**

COMA CORRECTOR



Coma 1 inch off-axis 17½'' f/4.5

Same field with LUMICON coma corrector; smaller, more numerous stars.

This computer-designed LUMICON 2'' lens reduces coma and flattens the field for both viewing and photography. **It threads into LUMICON 2'' EASY-GUIDERS for effortless installation.** This zero power lens does not change image scale nor shift focus, and all lens surfaces are multi-coated for highest efficiency. Clear aperture = 1.8''.

LUMICON 48mm Coma Corrector/Field Flattener Lens	**$285.00**
LUMICON 2'' EASY-GUIDER	**$169.50**
2'' EASY-GUIDER (Mamiya 645)	**$199.50**
2'' Adapter for Pentax 6X7	**$129.00**
2'' Adapter for Hasselblad	**$229.00**
2'' Adapter for Bronica SQ-A	**$175.00**
2'' Extension for viewing	**$26.00**

2'' DELUXE BARLOW

1.8x Multiplier Lens (2'' Barlow)

LUMICON 1.8x Multiplier Lens (2'' Barlow)	**$235.00**

LARGE UV/DUST SEAL

Protect the optics of your 8-14'' Schmidt-Cassegrain with a UV/Dust Seal. Simply thread it onto the rear cell, then attach all normal accessories. The large size fits Meade 2120, Celestron-11 and -14 & has a high quality multi coated (removable) 72mm UV filter.

Deep-Sky Filter/Dust Seal for C-8, 2080	**$119.50**
UV/Dust Deal for Celestron C-8	**$39.00**
UV/Dust Seal for Meade 2080, 2045	**$39.00**
UV/Dust Seal (large) for Meade 2120	**$89.50**
UV/Dust Seal for Celestron-11, -14	**$89.50**

LOW PROFILE FOCUSERS
New! Thread-on for Odyssey

FROM $59.50

LUMICON® LOW PROFILE FOCUSERS

LUMICON now offers 3 different low-profile helical focusers. They stand only 1¼-1½'' above the telescope tube. Use the 1¼'' or 2'' versions for viewing. Use the 2'' non-rotating focuser for convenient photography with the LUMICON 2'' EASY-GUIDER™.

Select your desired base-plate shape! Coulter Odyssey (thread-on installation), Flat, 7'' OD, 9½'' OD, 12½'' OD, 16'' OD, 21'' OD.

LUMICON 1¼'' Helical Focuser	**$59.50**
LUMICON 2'' Helical Focuser 1½'' high	**$65.00**
LUMICON Non-rotating Helical Focuser	**$129.00**
2'' Astro Systems focuser, only 2'' high	**$139.00**
3 handles for non-rotating focuser	**$12.95**
2''/1¼'' adapter w/48mm filter threads	**$20.00**
2'' LUMICON EASY-GUIDER	**$169.50**

LUMICON 50mm, 80mm SUPER-FINDER™

Visual Astronomers prefer the LUMICON 80mm SUPER-FINDER™, since hundreds of deep-sky objects, including most Messier objects, are visible directly. SUPER-FINDERS also make nice small portable telescopes. 80mm aperture, F=300mm coated achromat or 50mm, F=200mm coated achromat. Eyepieces and/or star diagonal are extra.

1¼'' 50mm Finderscope **$59.50**, right-angle	**$59.50**
1¼'' straight-thru 80mm SUPER-FINDER	**$169**
1¼'' right-angle 80mm SUPER-FINDER	**$179.50**
1¼'' right-angle version, w/star diagonal	**$209**
25mm Cross-hair 1¼'' eyepiece (12X)	**$39**
Large mounting rings for 80mm Finder	**$55**
1¼'' Star Diagonal **$39**, Mounting Brackets,	**$39.50**
1¼'' 45° diagonal for correct left-right views	**$52.44**

LOTS OF ADAPTERS

2'' adapter for C-8, Meade 2080, etc.	**$26.00**
2'' adapter for C-80, C-100 refractor	**$39.50**
2'' adapter for C-70, C-80F, C-100F fluorite	**$39.50**
2'' adapter for C-6, Comet Catcher, Meade 312	**$30.00**

EXTENSION TUBES

1'' long 1¼'' OD thread-in extension	**12.00**
2½'' long extension (holds 1¼'' filters)	**16.00**
4½'' long extension for 1¼'' eyepieces	**$25.00**
3'' long extension for 2'' eyepieces*	**$26.00**
2'' long extension for 2'' eyepieces*	**$26.00**

VIEWING ADAPTERS

2''/1¼'' reducing bushing,threaded 48mm*	**$20.00**
2''/T-thread adapter, threaded 48mm*	**$25.00**
T-thread/1¼'' adapter	**$25.00**
F/10 2'' or 1¼'' eyepiece viewing adapter for Giant Easy-Guider	**$39.50**
Low profile star diagonal eyepiece holder	**$16.00**
Meade 2'' Diagonal/Giant Easy-Guider	**$39.50**

**Threaded to hold 48mm filters.*

Meade & Celestron
LUMICON Carries a full line of telescopes & accessories. Fast Delivery, competitive prices

LUMICON FOR HIGH PERFORMANCE

ASTROPHOTO OF THE MONTH

Galaxy M81 in Ursa Major. 75 minute exposure by Tony Hallas and Daphne Mount using hypered 2415 film and a LUMICON Giant Easy-Guider and C-14 telescope at f/7.5. Tony said, *If it wasn't for your accessories, these astrophotos wouldn't have been possible.*

"I'd Pick The TELE VUE™"

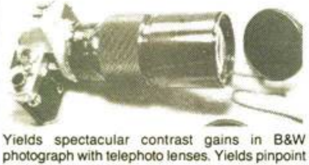
40mm Wide-Field Test, "Astronomy," Aug. 1990, p. 90

NEW! Genesis-SDF 4" f/5.4 SD-fluorite	**$1885**
Pronto 70mm f/6.8 apochromat w/2" diagonal	**$825**
Pronto 70mm f/6.8 w/45° erecting prism	**$725**
Complete Equatorial Mount	**$795**
Motor Drive for above mount	**$239**
7.4, 10.4, 13, 17, 21, 26mm Plossl 50°	**$79**
1.8x or 2.5x Tele Vue Barlow Lens	**$89**
2" Giant Barlow - 2x	**$189**
32mm Plossl, widest true field in 1¼"	**$109**
55mm 2" Plossl, widest possible field	**$219**
15mm Wide-Field, 1¼" eyepiece, 65°	**$135**
19mm Wide-Field, 1¼" eyepiece, 65°	**$145**
24mm Wide-Field, "Rich-Field!" 65°	**$169**
32mm Wide-Field, 2" eyepiece, 65°	**$239**
40mm Wide-Field, "Rich-Field!" 65°	**$299**
4.8mm Nagler, 82° field, 1¼" eyepiece	**$149**
7mm Nagler, 1¼" eyepiece, 82° field	**$189**
9mm Nagler, 82° field, 1¼" or 2"	**$219**
13mm Nagler, 82° field, 1¼" or 2"	**$249**
12mm Nagler, Type II, 82°, 1¼"/2"	**$249**
16mm Nagler, Type II, 82°, 1¼"/2"	**$289**
20mm Nagler, Type II, 82°, 2" only	**$340**
1¼" Paracorr Visual Coma Corrector	**$159**
2" Paracorr Visual Coma Corrector	**$249**
NEW! 15mm Panoptic 1¼", 68° field	**$199**
NEW! 22mm Panoptic 1¼"/2", 68°	**$249**
NEW! 27mm Panoptic 2", 68° field	**$299**
NEW! 35mm Panoptic 2", 68° field	**$325**

ADJUSTABLE PIGGYBACK MOUNT

The LUMICON adjustable piggyback mount is ideal for telescopes of 6-16" aperture. It permits **both** vertical and sideways adjustment for optical alignment. Also ideal to mount LUMICON 80mm SUPER-FINDER™, large telephoto lenses and small telescopes up to about 5 lbs.
LUMICON Adjust. Piggyback Mount **$59.50**
Specify telescope size: 6", 8", 10", 11", 14", 16"

H-ALPHA PASS FILTER



Yields spectacular contrast gains in B&W photograph with telephoto lenses. Yields pinpoint star images. Superb with hypered 2415. For color, use the Minus Violet (MV) Filter.

Specify Lens Size	**H-Alpha**	**(MV)**
46, 48, 49mm	**$59.00**	**$49.00**
52, 55, 58, 62mm	**$69.00**	**$59.00**
67, 72, 77mm	**$79.00**	**$69.00**
82mm	**$89.00**	**N/A**

Hypered 2415 film, 36 exp .. **$10.95, $3/$29**

LUMICON®

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NEW! ENHANCED ALUMINUM DIAGONAL MIRRORS BOOST TELESCOPE PERFORMANCE

LUMICON 1.3" & 2.1" enhanced aluminum diagonal mirrors & 1¼" star diagonal.

The new LUMICON diagonal mirrors have a special enhanced aluminum coating with a protective overcoating for long life. Visible reflectivity is 94-96% compared to 86-89% for standard aluminum coated mirrors. The extra 5-10% transmission is like adding up to an inch of aperture! The substrate is fine annealed Pyrex flat to 1/8 wave.

1.32" **$39.50** 1.52" **$45.00** 1.83" **$49.50**
2.14" **$59.50** 2.60" **$75.00** 3.10" **$99.50**

ENHANCED ALUMINUM STAR DIAGONAL

90° star diagonals with 96% reflectivity enhanced aluminum mirrors in a CNC machined black anodized aluminum body. Performance far exceeds prism diagonals.

1¼" (1.32" mirror)	**$99.50**
2" (1.83" mirror)(see photo above)	**$159.00**

LUMICON FILTERS — BEST IN THE WORLD!

"The LUMICON OIII proved to be our favorite... It gave the greatest contrast gain."
ASTRONOMY February 1991

AMAZING OIII FILTER™

Helix Nebula, NGC 7293 in Aquarius. Bright and easy with Lumicon Oxygen-III Filter.

The ultimate in filter performance! The Lumicon Oxygen-III Filter has a contrast twice as high as the high performance Lumicon UHC Filter™. Use the Oxygen-III Filter for observing the very faintest planetary and diffuse emission nebulae. Also gives incredible views of bright nebulae (like M-27, M-17, etc.) from urban locations. Bandpass is 11nm, transmission is 90-96% for both O-III lines at 496nm and 501nm.

SEE THE HORSEHEAD!

Horsehead Nebula in Orion. This faint nebula is seen best with a LUMICON H-Beta Filter. Photo by J. Marling using a Deep-Sky Filter.

"I CAN SEE THE VEIL NEBULA!"

Rich Zepernick saw the Veil Nebula for the very first time with a **LUMICON UHC Filter**. He stated, *"It was actually there! and not just around 52 Cygni, but the whole loop! Words cannot possibly express my feelings. I don't know how I managed without these filters."*
Rich Zepernick, Cresskill, NJ

DEEP-SKY FILTER™

BEST for Astrophotography!

"Stunning is all I can say," says noted astrophotographer Jack Newton. Great for BOTH color and black and white photography.

BEST WIDE-BAND FILTER!

"Based on our tests we'd recommend a LUMICON Deep-Sky and Oxygen-III as complementary filters. The LUMICON Deep-Sky Filter clearly had the best contrast for ***reflection*** *nebulae."*
Astronomy, Feb. 1991

	Premium*
0.96" LUMICON DEEP-SKY Filter threads into most 0.96" eyepieces	**$59.50**
1¼" LUMICON DEEP-SKY Filter threads into most 1¼" eyepieces	**$79.50**
48mm LUMICON DEEP-SKY Filter (1.7" aperture), threads into most 2" eyepieces. Also fits LUMICON EASY-GUIDERS	**$119.50**
2" LUMICON DEEP-SKY Filter (1.5" aperture), threads into most 2" eyepieces. Also has male & female camera T-threads for prime focus photography	**$119.50**
72mm LUMICON Giant DEEP-SKY Filter (62, 67, 77mm adapter, $8)	**$299.50**
2" Rear Cell Filter, fits SCT's ... Deep-Sky, **$119.50** UHC, O-III, H-Beta,	**$199.50**
1¼" LUMICON UHC Filter threads into most 1¼" eyepieces	**$99.50**
48mm LUMICON UHC Filter (1.75" aperture) fits most 2" eyepieces	**$199.50**
Set of both premium **DEEP-SKY** and **UHC Filters** (Save 11%) ... 1¼" **$159.50**; 48mm	**$279.50**
LUMICON H-BETA Line Filter (9mm bandpass at 486nm). For the California Nebula, Horsehead Nebula, and other extremely faint nebulae. **1¼"** ... **$99.50, 48mm**	**$199.50**
Oxygen-III Filter for very faint planetary and diffuse nebulae, 11nm bandpass at 496nm and 501nm O-III lines ... **1¼" $99.50, 48mm**	**$199.50**
Telephoto lens adapter for 2" or 48mm filter. Select 46, 49, 52, 55, 58mm	**$6.95**
Universal adapter for 1¼" filters. Adapts the 1¼" filters to any 1¼" eyepiece	**$16.00**
Universal adapter for 48mm or 2" filters. Allows use of any 1¼" eyepiece	**$20.00**

**Premium filters are currently the best in the world. All Lumicon filters include individually measured transmission data.*

DEEP-SKY ASTROPHOTOGRAPHY

SR-V 3200 NEW FILM

FILM HYPERSENSITIZATION KITS†

LUMICON HYPER-KITS™ yield 3-15x film speed gain in long exposures. They are safe & simple to use. Easy HYPER-KIT includes a chamber with all controls and fittings, thermometer, a refillable cylinder of non-flammable forming gas & hand-operated vacuum pump.

U.S. Patent 4,473,636

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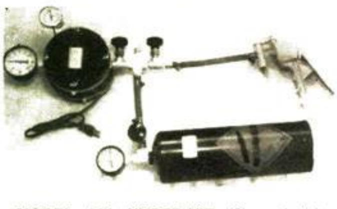
MODEL 300 HYPER-KIT sensitizes any 35mm film in hours. Best for 2415. Achieves highest possible film speeds **$325**



MODEL 600 HYPER-KIT (See photo) Like the Model 300, but also sensitizes 120/220 larger format film and small glass plates **$395**

MODEL 1200 HYPER-KIT is for 4X5" plates and film up to 5X7". Has 2 gas cylinders and includes temperature controller ... **$595**

Temperature controller for any HYPER-KIT **$65**

Electric Vacuum Pump, Model R-10 **$325**

GUIDE OFF-AXIS FOR LOVELY ASTROPHOTOS

All **LUMICON EASY-GUIDER™** off-axis guiders† have both radial and 360° rotational adjustments for 5X easier guide-star selection, use 48mm filters, 360° camera rotation, large prisms for bright guide-stars.
Specify Camera and Telescope type.
U.S. Patent 4,448,500

NEWTONIAN EASY-GUIDER™

Full aperture. Installs in seconds. Specify 2" or 1¼".

NEWTONIAN EASY-GUIDER	**$169.50**
3X Relay Diagonal (see photo)	**$89.50**
Illuminated reticle eyepiece, pulsed	**$109.50**

Guider for Hasselblad **$350,** Mamiya 645 **$199**
Pentax 6X7 **add $119;** Pentax 645 **add $139**

CASSEGRAIN EASY-GUIDER™

For C-8, Meade 2080, Cynamax-8. Includes 50mm achromatic lens for f/5.8 operation—3X shorter exposures! **Superb rich field viewing, too!**

CASSEGRAIN EASY-GUIDER **$225.00**
Adapter for Hasselblad **$198,** Mamiya 645 **$98**
Pentax 6X7 **add $119;** Pentax 645 **add $139**

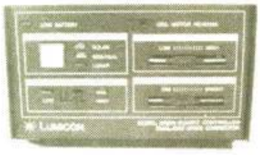
GIANT EASY-GUIDER™

For Celestron-11, C-14, and the 10" Meade 2120. Includes 80mm clear aperture achromatic lens for edge-to-edge illumination & pin-point star images. F-ratio adjustable f/4-f/11. **Also yields unmatched Rich-Field viewing.**

GIANT EASY-GUIDER **$395.00**
48mm DEEP-SKY Filter ordered with any EASY-GUIDER (SAVE $20) ...... **add $99.95**
Adapter for Hasselblad **$295,** Mamiya 645**$149**
Pentax 6X7 **add $129;** Pentax 645 **add $149**

WHAT DO YOU NEED?

1. Illuminated reticle eyepiece **$99.50**
Lumicon 12mm eyepiece system has adjustable LED illumination, dual crosslines, battery pack.
2. Cable release for long exposures .. **$9.95**



3. **LUMICON Digital Drive Corrector** . **$249**
Dual-axis drive corrector is essential for astrophotography and/or field use of your telescope. 30Hz/90Hz variable output controls telescope drive. 60Hz digital reference ±12VDC Declination control output. Both 110VAC and 12VDC input for home or field use. Dec. reverse switch for Newtonians.

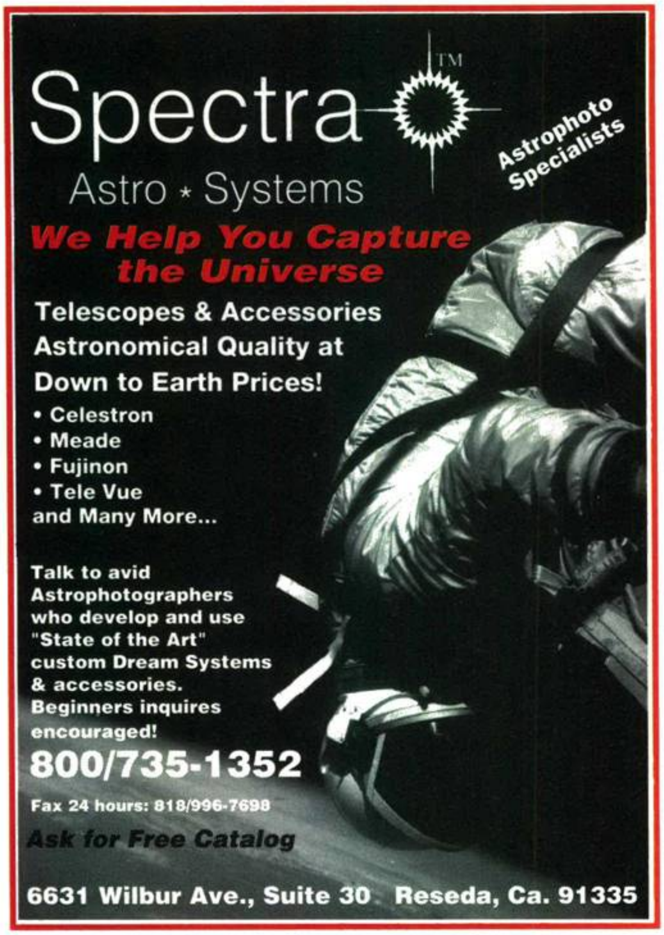
Declination motor (state telescope) ... **$109**
Variable dec. speed drive w/built-in 5AH battery **$299**

NEW
SRV3200

HYPERSENSITIZED FILM

LUMICON Hypersensitized film is essential for good deep-sky astrophotography. Deduct 10% for 3 or more rolls (mixed o.k.). ***No C.O.D.s.***

Film Type, 35mm	**Exposures**	**Price**
2415, Ultra-fine B&W, red sens.	36	**$11.95**
SR-G3200, fastest of all, color neg	24	**$13.95**
Kodak Ektar 1000 fast, fine grain	24	**$12.95**
Fuji HG400 fine grain color neg.	12	**$13.95**
3M 1000, fastest slide film	12	**$12.95**
Fujichrome RD100, fine grain slide	24	**$12.95**
D-19 B&W Developer	1 gal.	**$6.95**



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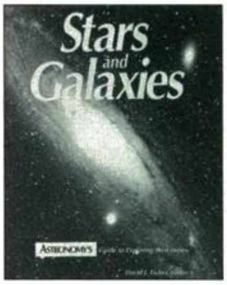
Stars and Galaxies: ASTRONOMY'S Guide to Exploring the Cosmos



Take a lavish tour of the sky's most appealing regions with binoculars or a small telescope. *Stars and Galaxies* introduces you to the brightest, most beautiful and most challenging citizens of the Milky Way Galaxy and beyond. The tour includes 344 star clusters, nebulae, and galaxies visible in backyard telescopes.

Written by a diverse group of amateur astronomers, this guide is handy next to your telescope or as a reference on your astronomy bookshelf. Edited by David J. Eicher, associate editor of ASTRONOMY magazine. 8½ x 11, 192 pgs., 129 b&w and 110 color photos, 98 illus., hrdbd. #18536........ **$29.95**

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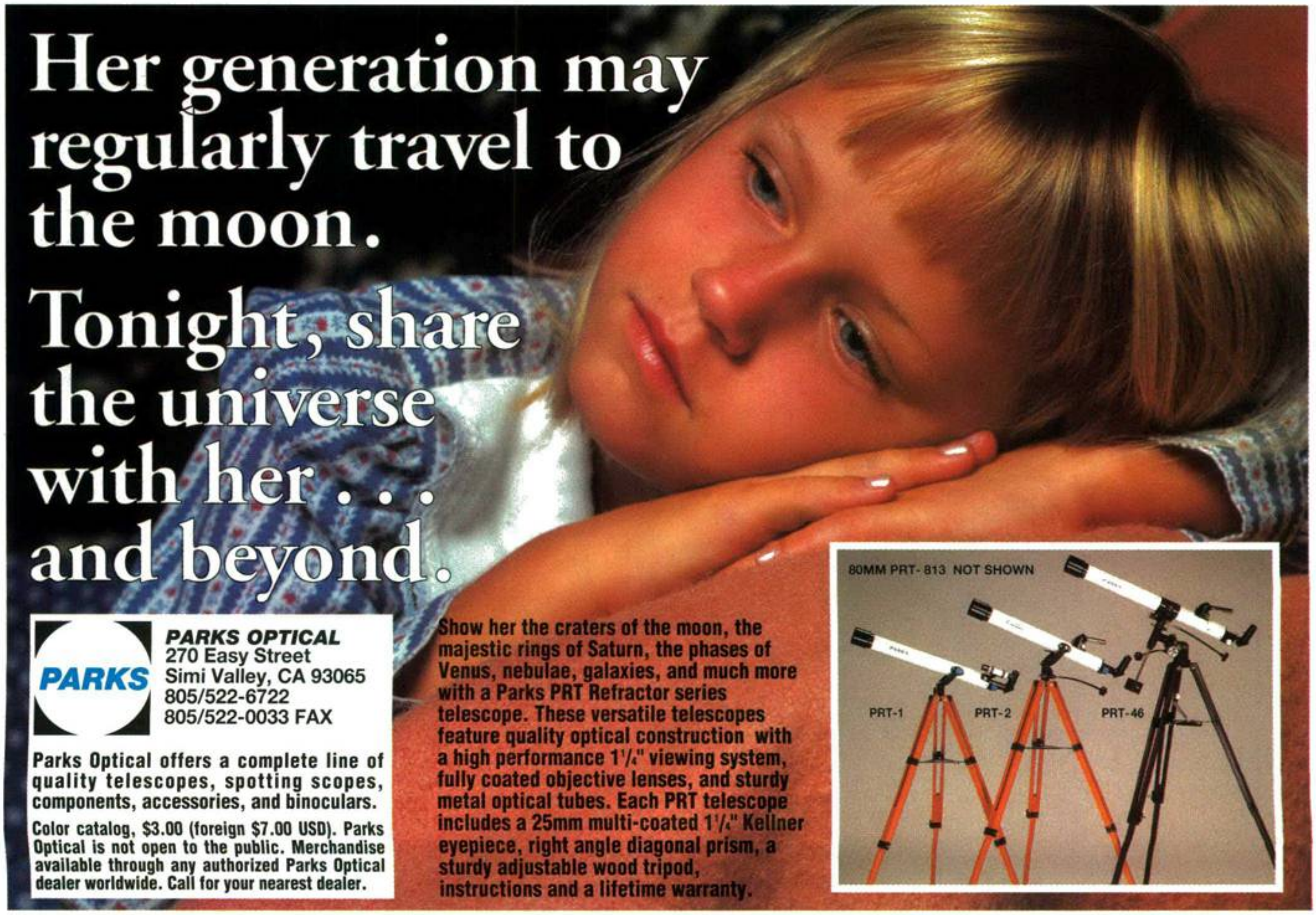

Her generation may regularly travel to the moon.

Tonight, share the universe with her . . . and beyond.

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805/522-0033 FAX

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Show her the craters of the moon, the majestic rings of Saturn, the phases of Venus, nebulae, galaxies, and much more with a Parks PRT Refractor series telescope. These versatile telescopes feature quality optical construction with a high performance 1¼" viewing system, fully coated objective lenses, and sturdy metal optical tubes. Each PRT telescope includes a 25mm multi-coated 1¼" Kellner eyepiece, right angle diagonal prism, a sturdy adjustable wood tripod, instructions and a lifetime warranty.

Photographing the Milky Way

The Summer Milky Way

by Timothy Printy
(28mm f/4 lens with 0.42x fisheye adapter, Fuji Super HG 400 film, 30-minute exposure)

Star Trails over Monument Valley

by Chris Dunmill
(35mm lens at f/3.5, Fujichrome 100 film, 5-minute exposure)

"There's something special about capturing the glow of the Milky Way as it cuts across the entire sky," says Timothy Printy of the Astroscopers Astronomy Group in Chiefland, Florida. And he's right: A portrait of the summer Milky Way includes some of the sky's outstanding hunting grounds for backyard observers — Sagittarius, Scorpius, Cygnus, Lyra, and Scutum.

Printy made the image (above) at the Astroscopers' annual cookout and star party on May 22, 1993. "Many members were present," reports Printy, "including Tom and Jeanne Clark with their 36-inch f/5 reflector. We observed a variety of galaxies including the big face-on spiral M101 in Ursa Major. I'll never look at that galaxy the same way again," says Printy, with a tinge of nostalgic regret.

Observing Comet Mueller. On January 2, 1993, Jean Mueller of Palomar Observatory discovered a 15th-magnitude comet in Ursa Major. Designated Comet Mueller (1993a), it gradually brightened throughout 1993 and was observed by hundreds of backyard astronomers.

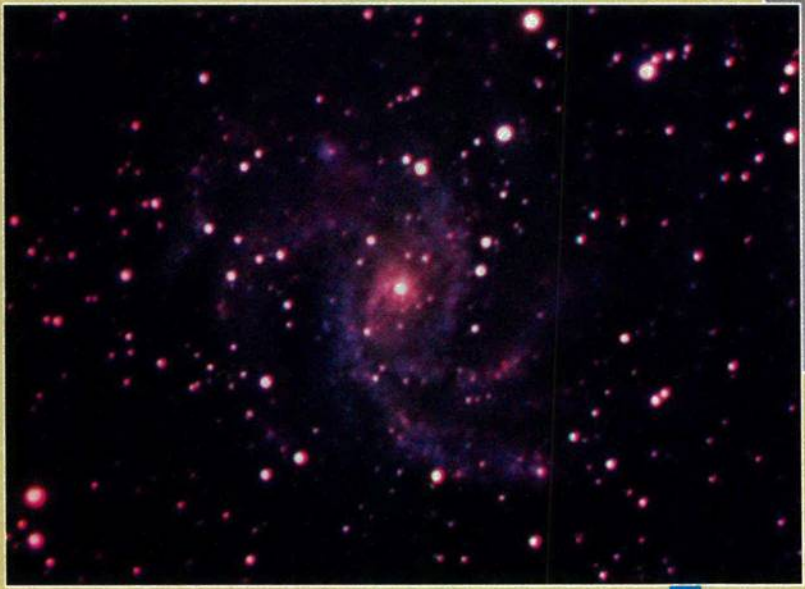
One such comet tracker was Richard Didick of Rehoboth, Massachusetts. Didick observed Comet Mueller using an 8-inch f/8 reflector beginning on August 22 and kept a journal of observations until October 23. In late August Didick described the comet as glowing at about 11th magnitude, "diffuse and very slightly brighter toward its center." By late September Didick estimated the comet's brightness at 10.5 and detected a short tail and fan-shaped coma. A sketch made on October 6 shows the comet had a prominent fan-shaped coma and a very bright nucleus. On October 19 the comet glowed at magnitude 9.9 and its tail spanned 7'. Six days later Didick observed the comet occulting a bright star.

Several weeks earlier, on August 16, 1993, Mueller had discovered another comet, Comet Mueller (1993p), this one a 14th-magnitude object near the Andromeda-Perseus border.

The Moon Occults Venus. "As I drove to work all I could think about was the occultation," reports Thomas S. Parry of Oakton, Virginia. Parry anticipated the fact that the Moon would briefly cover Venus at 12:20 p.m. EST on April 19, 1993. The day was partly cloudy and Parry had never witnessed the occultation of a planet by the Moon. After breaking away from the office, he dashed home under a deteriorating sky but soon found himself gridlocked on Interstate 50.

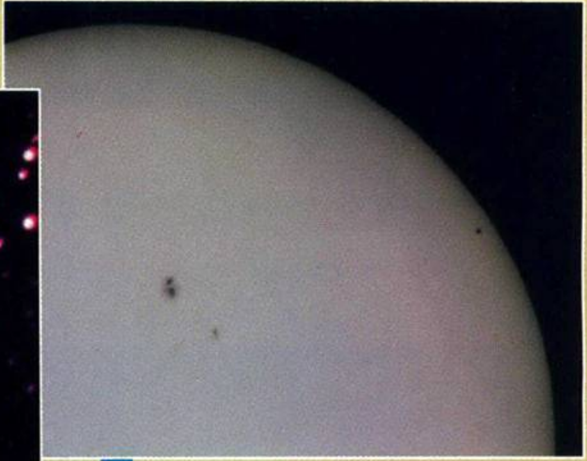
"My heart sank," says Parry, "but I made it home by 11:55 and with my wife's help set up my 14.5-inch scope and readied a pair of binoculars. "The sky was clear as the Moon approached Venus, and I watched in amazement," he says. "The twin cusps of Venus' crescent stood on the bright lunar limb, and with seemingly increasing speed, the planet sank into invisibility." Parry recommends observing occultations to anyone who has not done so because he feels they are too often neglected. ☐

ASTRONOMY wants to hear about your observations of the sky. Send reports, sketches, and photographs to David J. Eicher, Reader Reports Editor, ASTRONOMY, P.O. Box 1612, Waukesha, WI 53187. Please label each submission with name, address, and social security number.



Spiral Galaxy NGC 6946

by James R. Foster, Michael A. Stecker, and William Fletcher (14-inch SCT at f/7, composite image of hypersensitized Tech Pan exposures: 156 minutes, with a Lumicon Hi-Performance filter; 84 minutes, using a Wratten #11 filter; and 90 minutes, using a Wratten #23A filter)

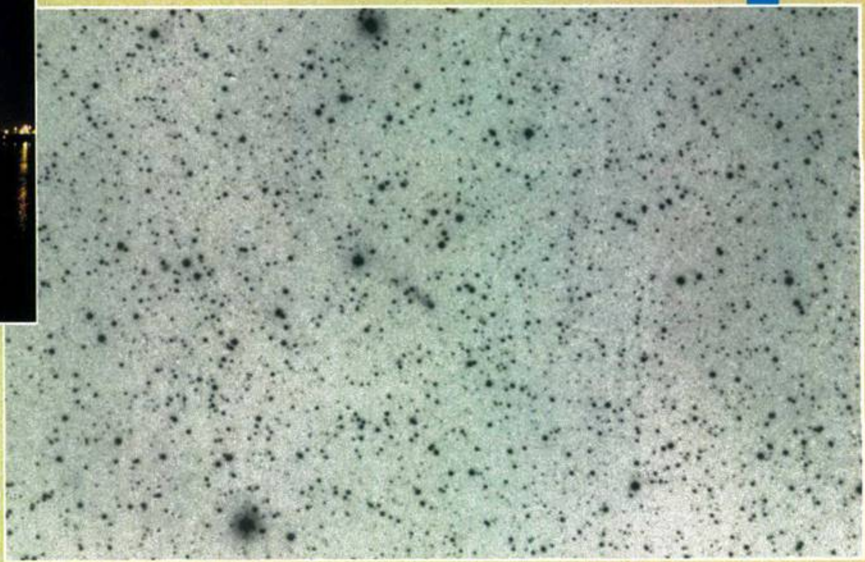


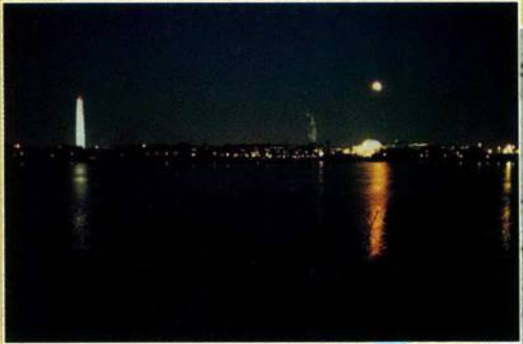
Mercury Transits the Sun

by Lin Ben Chu
(Takahashi FC 100 telescope, Vericolor HC film, 1/250-second exposure on November 6, 1993, from Taiwan City, Taiwan)

Comet Ashbrook-Jackson (1992i)

by Gerald Rhemann
(8-inch Schmidt camera, composite of 6- and 7-minute exposures on October 10, 1993)





Lunar Eclipse Over Washington Monument and Jefferson Memorial

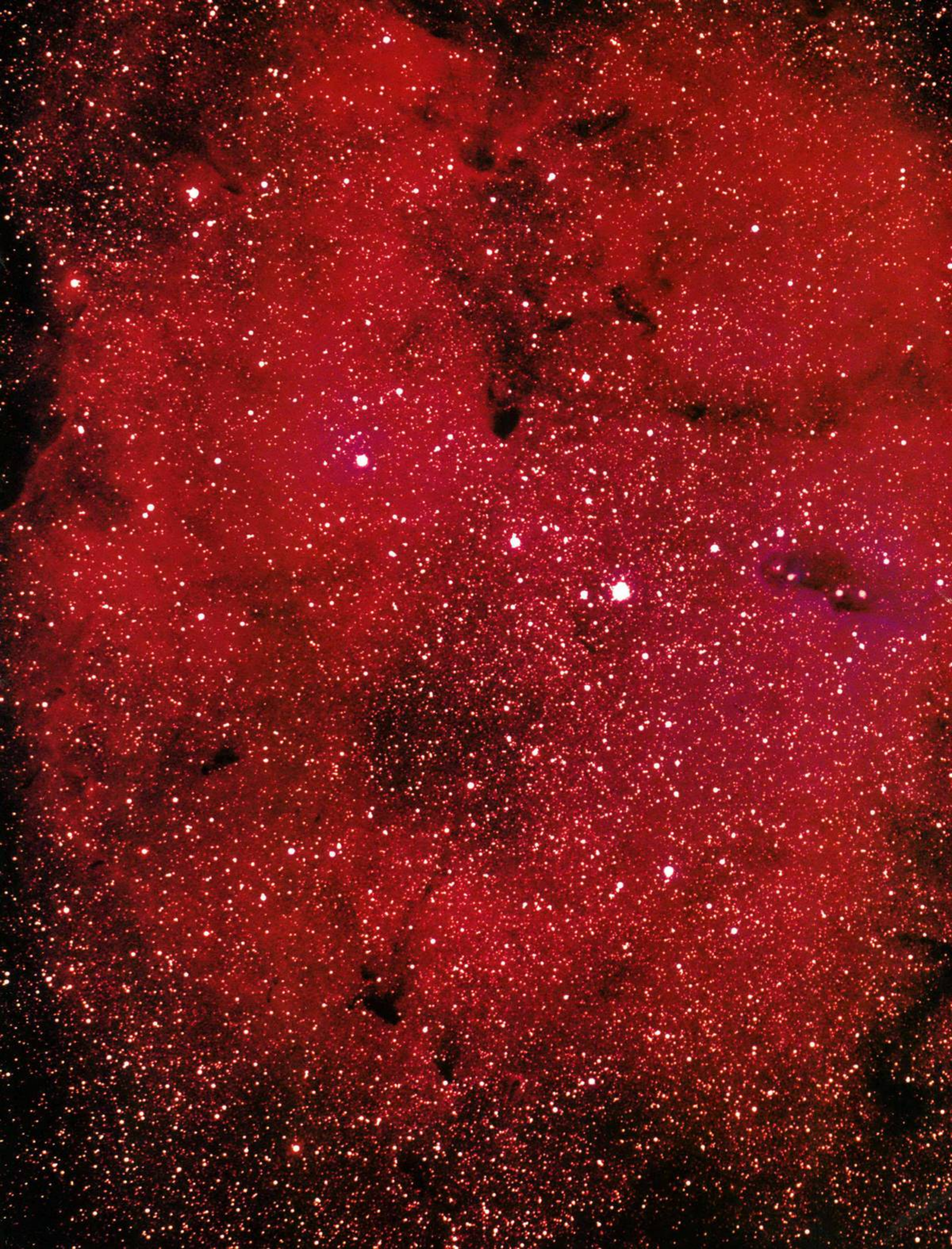
by Andre Bormanis
(35mm lens at f/3.5, Ektachrome 800 film, 6-second exposure on December 9, 1992)

RUDDY GAS AND WHITE-HOT STARS

Dozens of large emission nebulae dot the Galaxy's spiral arms and efficiently convert gas into newborn stars. It's the culmination of an ongoing process of celestial recycling. George Greaney's photograph of IC 1396 in Cepheus, a bright emission nebula (opposite page), captures both the red glow of the hydrogen gas and the brilliant gleam of white stars in its center. The photo wins this month's $100 "Best Astrophoto" award.

Emission Nebula IC 1396

by George Greaney
(6-inch f/7.1 apochromatic refractor, hypersensitized Fuji Super HG 400 film, composite of two 50-minute exposures)



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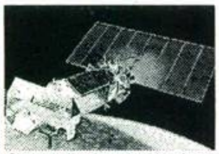

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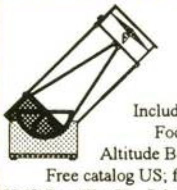

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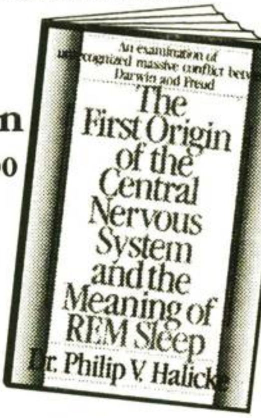
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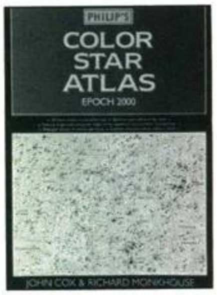

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Terence Dickinson, (Camden House, 1993; distributed by Firefly Books), ISBN 0-921820-71-2, 151 pages, softcover, $12.95.

Dickinson poses fifty of the most asked questions about the universe and then provides brief, nontechnical, and up-to-date answers. He organizes these into six sections: aliens and more, the universe, the Sun and Moon, planets, stars, and stargazing. Each section has six to twelve questions, with the section on the universe garnering the most questions.

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Archie Roy, editor, (Oxford University Press, 1992), ISBN 0-19-869140-8, 200 pages, hardcover, $45.

The concise entries of this book make it more properly an illustrated astronomical dictionary. But whatever you call it, it will help explain to beginning astronomers more than 1,100 terms and concepts they are likely to find in astronomical books and magazines. Almost 200 full-color photos and illustrations accompany the entries. This encyclopedia is one of the few to include such items as biographical notes on famous astronomers and the astronomies of China and Islam.

Moons and Planets

William K. Hartmann, (Wadsworth, Inc., 1993), ISBN 0-534-18894-X, 510 pages, acid-free paper, hardcover, $40.

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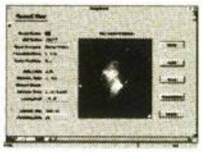

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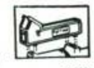

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want to learn more about why the planets are the way they are and how astronomers learn about the planets will also glean a great deal from this book. Hartmann relegates mathematical discussions to separate boxes: This leaves the physical and astronomical arguments in the main text and permits the mathematically disinclined reader to obtain a descriptive overview of these arguments.

Instead of writing separate chapters about each planet, Hartmann uses physical principles to provide a cohesive picture of planetary phenomena. For example, he discusses the atmospheres of all the planets in one chapter and their interiors in another.

The effects of impacts, volcanism, tectonics, and water and wind erosion on planetary surfaces appear in two chapters. Because the orbits of the planets affect many of their characteristics, early in the text Hartmann discusses orbits (and the physically related topics of rings and gravitational tides). And because planets wouldn't exist without a star to form around, he discusses how stars themselves form.

Touch the Stars

Noreen Grice, (Museum of Science, Science Park, Boston, MA 02114-1099, 1993), ISBN 0-7167-2396-4, 53 pages, softcover, $19.95.

This Braille and large-type edition introduces persons with visual impairments to the wonders of astronomy, providing both text about and tactile illustrations of stars, planets, and galaxies. This second edition adds an index and almost doubles the number of illustrations contained in the first edition.

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Tape and text by Tonja Evetts Weimar, (Pearce-Evetts Publishing, 1993), ISBN 0-936823-11-9, 101 pages, hardcover, $13.95.

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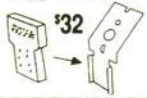

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Huge Selection of Astronomy Binoculars

50mm Orion Observer™ II Binoculars — 7x, 10x, & 12x

Fine quality, moderately priced binoculars, excellent for both astronomy and daytime observation. Fully coated optics, unique hand strap for a secure and comfortable grip. Include case and straps.

7x50 #9643 **$ call**
10x50 WA #9644 **$ call**
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50mm Explorer™ Binoculars

High performance large diameter binoculars with BAK-4 prisms and multi-coatings. Great for both astronomy and daytime observation. Comfortable ergonomic body design. Include case and straps

7x50 #9306 **$ call**
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New! 10x50 Orion UltraView™

The perfect binocular for eye and sunglass wearers. Extra-long 22mm eye relief and unique rubber pop-down eyepiece guard allows viewing with or without eyeglasses. Fully multi-coated optics provide high light transmission and maximum contrast compared to standard coated types. BAK-4 prisms. Wide 6.5° field of view. Close focus 16'. Weighs 32 oz. Includes case and straps.

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New! 10x50mm Orion Vista™

Superb for long distance nature observation and astronomy. The image quality will amaze you even when compared to much higher priced binoculars. Fully multi-coated optics provide high-fidelity true color images without ghousting or other aberrations. Long 16mm eye relief and roll-back eyecups for eyeglass wearers. BAK-4 prisms. 5.3° field of view. Weighs just 28 oz. Includes deluxe hard carrying case, rain shield, lens caps, and straps.

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Orion® 70mm FMC Giants

The standard for handholdable astronomy binoculars. Fully Multi-Coated. 33% lighter—weighs only 58 oz.—yet the same brightness and 7mm exit pupil as our 11x80 MC model. Superior 'BCF' body design. Includes: soft rubber eyecaps, tripod mounting adapter, durable hard carrying case, lens caps and straps.

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80mm FMC Giant Binoculars

20% more light transmission than ordinary "fully coated" binoculars. Fully Multi-Coated optics and superior BAK-4 prisms provide fantastic contrast and greatly improved edge sharpness.

11x80 MC- Brightest, widest field available. Ideal for deep-space observation under dark skies. Handholdable. #9502 **$ call**

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20x80 MC- Highest power model perfect for smaller deep-space objects and long range daytime views. Tripod required. #9498 **$ call**

Orion® 8x56 Mini Giants

56mm objective lenses gather over 2.5x the light of ordinary 7x35 binoculars. Perfect for viewing faint celestial objects, daytime viewing. Best Multi-Coated BAK-4 optics. 6° field of view. Standard model 33 oz. Rubber Armored for protection from bumps. Weighs 37 oz.

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Rubber Armored Model #9627 **$ call**

SuperGiant™ 100mm Binos

Gigantic, almost 4" lenses gather 156% of the light of 80mm binoculars. Individual eyepiece focus, fully Multi-Coated optics and BAK-4 prisms. Tripod mounting plate, metal-clad case. Weight 7.5 lbs., height 13.5".

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25x100 #9497 **$ call**
Shipped by FedEx only.

Observing Aids

NEW! Eyepiece/Accessory Cases

With patented unbreakable latches, die-cut foam inserts.
Inside Dimensions shown
11"x7"x3" #5951 **$ call**
12.5"x9"x5" #5952 **$ call**
16"x11"x5" #5953 **$ call**

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Gently replaces lost heat, a sure-fire cure for dew problems.

8" Dew Zappers—fit all Meade & Celestron 8" SCs
DC #3503, AC #3504 **$ call**
10" Dew Zappers—fit all Meade 10" SCs
DC #3506, AC #3508 **$ call**
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Forms into a tube with Velcro closure, opens flat for storage and travel. Models to fit most telescopes.

8" Celestron/Meade SC #4200 **$ call**

Other sizes available for scopes 3.5" to 14"—See our catalog for details

Scope Saver Telescope Covers

Keep the dust and dew away with these waterproof nylon covers; drawstring closure with cord lock.

8" Model
#15130 **$ call**

10"-11" Model Fits Meade 10" and Celestron 11"
#15131 **$ call**

Now available for Deep Space Explorers!

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Components

Parabolic Primary Mirrors

Excellent hand-figured parabolic mirrors guaranteed to meet theoretical limits of resolution. Fine polished, coated twice: with Aluminum and Silicon monoxide. Very competitively priced! *See catalog for pricing.*

Standard Primary Mirrors
Made from fine soda-lime plate glass, 1:8 thickness ratio. Guaranteed 1/8 wave. Sizes: 6" f/8, 8" f/6, 10" f/4.5, 12.5" f/6.

Pyrex Low Expansion Mirrors
Made from fine annealed Pyrex brand low expansion glass, 1:8 thickness ratio. Guaranteed 1/10 wave. Available with 94% reflectivity Enhanced Aluminum coatings. Sizes: 6" f/5, 6" f/8, 8" f/6, 10" f/4.5, 10" f/6, 12.5" f/6.

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Made from fine annealed Pyrex brand glass, aluminized and SiO overcoated. Guaranteed 1/10 wave accuracy. Available with Enhanced Aluminum coatings. Nine sizes from 1.00 to 4.00" minor axis. *See catalog for pricing.*

Finder Scopes New!

These are high-quality finders at incredibly low prices! Fully coated wide field achromatic optics with adjustable focus. Precision crosshairs. White or black enameled metal tube.

6x30mm — Same unit used on $1000+ "big name" telescopes. With 2-ring bracket, fits scopes 6"-12". #13023 (white) **$ call**

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8x50mm—2.7x light grasp of 30mm models. Bright 6.25mm exit pupil. #7090 (white) #7094 (black) **$ call**

8x50mm Illuminated—Wireless illuminator with adjustable brightness. #7092 (white) #7096 (black) **$ call**

9x60mm — 44% more light grasp than 50mm models. #7091 (white) #7095 (black) **$ call**

9x60mm Illuminated—Wireless illuminator with adjustable brightness. #7093 (white) #7097 (black) **$ call**

Mounting Brackets - Unique sliding dovetail design. Super high quality. Fits any scope 6" and over including Celestron & Meade SCs.

8x50mm bracket #5040 **$ call**
9x60mm bracket #5041 **$ call**

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Finest in their class. Diagonal-cut plated brass racks, oversized knurled knobs, long focus travel.

1.25" #13007 **$ call**

2.0" includes 1.25" adapter. #13003 **$ call**

NEW! Low-Profile Focusers

Perfect for fast optical systems. Ideal replacements for "Odyssey" scopes.

1.25"-#13014 **$ call**
2.0" - #13016 **$ call**

Night Vision Flashlights

An essential accessory for astronomers. Choose from our wide selection.

Astronomer's Flashlight #5701 **$ call**
Nitewriter Pen #5709 **$ call**
Hands-Free Flex Light #5707 **$ call**
Starlite LED Flashlight #5714 **$ call**
Celestron LED Flashlight #5720 **$ call**

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Deluxe Model—Built for professional musicians. Extra heavy duty.
#5934 **$ call**

Accessories See Our Catalog for Even More!

45° Erect Image Diagonal Prisms

See the world as it really is with Orion's 45° erect image diagonal. Ideal for all refractors and compound telescopes used for terrestrial viewing.

1.25" Diagonal #8790
.965" Diagonal #8791
Hybrid 1.25"/.965" Diagonal #8792

$ call

90° Star Diagonal Prisms

Orion's multi-coated diagonals let you view at a right angle from the direction your telescope is pointing. The image is backward. Ideal for refractors and Schmidt-Cassegrains used for astronomical viewing.

1.25" Star Diagonal #8763 **$ call**
Hybrid 1.25"/.965" Star Diagonal #14008 **$ call**
.965" Star Diagonal #8761 **$ call**

2" Prism/Mirror Diagonals

2" Prism Diagonal–Absolutely the finest quality multi-coated 2" prism for highest light transmission.

For refractors #8770
For Schmidt-Cass. #8771

$ call

2" Mirror Diagonal– Affordable, high-quality star diagonal.

For refractors #8773
For Schmidt-Cass. #8772 **$ call**

Universal Camera Adapters

For prime focus or eyepiece projection astrophotography.

.965" #5268 **$ call**
1.25" #5264 **$ call**
Hybrid 1.25"/.965" #8782 **$ call**

Variable Power Camera Adapter

Allows variable projection distances during eyepiece projection photography. For 1.25" eyepiece holders.

#5262 **$ call**

Tele-Extenders

For high powered photography with your Meade, Celestron 4", 8", 10", 11", 14" Schmidt-Cassegrain.

Standard Tele-Extender #5125 **$ call**
Variable Tele-Extender #5127 **$ call**

T-Adapters

Threads to rear cell of telescope, requires t-ring for your camera model.

for SC #5116 **$ call**
for C-90 #7115 **$ call**

T-Rings

Available for many different camera types, call toll-free or see our catalog for your particular model.

Multi-Function Focal Tester

Allows easy, accurate, ultra-sharp focusing, essential for astrophotography.

#7109 **$ call**

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Bogen/Velbon/more!
Huge selection of tripods available, for telescopes, spotting scopes and giant binoculars. Choose from assembled models or mix-and-match pan heads and tripods, sold separately. See our catalog for details.

Orion Slow Motion Adapter

Attaches to your photo tripod pan head. 2 slow motion control knobs to make precision adjustments in altitude and altazimuth. Very handy for tracking planets, the Moon, etc. with refractor telescopes and small spotting scopes. Attaches with a standard 1/4-20 thread.

#7012 **$ call**

Extension Cable for Slow Motion Control

12 3/4" flexible cable, for tracking at high powers. Buy 2, one for each axis.

#5014 **$ call**

StereoScope Viewer

For comfortable two-eyes-open observing. You won't believe the views! Threads securely to the rear cell of your telescope. Requires two identical eyepieces.

#9720 **$ call**

f/6.3 Reducer/Corrector

Get f/6.3 performance from your f/10 Schmidt-Cassegrain.

#5120 **$ call**

NEW Model 3

Sky Wizard™

Electronic Finder & Sky Catalog

Let Sky Wizard do the work, while you relax and have fun observing!

- Find any celestial subject in 15 seconds!
- One minute setup — no polar alignment or levelling.
- Observe hundreds of objects in a few hours!
- For ANY telescope, with or without a motor drive. *Even altazimuth or Dobsonian scopes!*
- Digital display of celestial coordinates (RA & Dec).
- Built-in electronic sky catalog — find subjects by their common catalog name, not their coordinates. Complete with object descriptions.
- Powered by a single 9v battery. Weighs just 6 oz!

Complete system requires Sky Wizard Model 1 or 2 and a telescope installation package, sold separately.

Encoders and cables available separately for custom installations. Call for details.

Sky Wizard Model 1
Includes the Messier Deep Space Catalog of 110 objects, 28 bright stars, and the planets.

#7801 **$ call**

Sky Wizard Model 2
Huge 2100+ object database, plus a user catalog to store 27 objects of your choice.

#7802 **$ call**

Sky Wizard Model 3
Gigantic 10,000 object database, expanded subject descriptions, RS-232 port.

#7803 **$ call**

Installation Packages
Includes 2 encoders, all required mounting hardware and brackets, connecting cables, and complete illustrated instructions.

Celestron Super Polaris	#27100	**$ call**
Celestron Ultima 8" & 11"	#27101	**$ call**
Celestron Great Polaris	#10303	**$ call**
Celestron C-5	#10304	**$ call**
Celestron G-11	#10305	**$ call**
Celestron Classic 8" & Powerstar 8"	#27102	**$ call**
Meade 8" & 10"	#27103	**$ call**
Dobsonian (fits Coulter and most others) Call for stock # for your model		**$ call**

Installation packages available for other telescopes.

Orion Off-Axis Guider

Allows you to observe a guide star during photography. Multi-coated.

#5144 **$ call**

Orion UltraGuider

Wide-range lateral prism adjustment; precision helical focusing; adjustable camera focal plane position.

#5139 **$ call**

110v Motor Drive for Refractors

Fits Orion equatorial mounts, many others. Plugs into any standard AC outlet.

#17001 **$ call**

12 Amp Hour Porta Pac Battery

Ideal for high power-consuming accessories. With carrying case. Weighs only 10 lbs.

#2354 **$ call**

Filters

Glass Solar Filters

High-quality optical glass filters, for superb images of the sun with your telescope. Triple-coated with advanced scratch-resistant stainless steel alloy. Great for both visual and photographic use. Slide fits over the front of your telescope.

For 8" SCs #7713 **$ call**
For 10" SCs #7715 **$ call**

NEW! *Solar glass filters for Deep Space Explorer reflectors. Many other sizes available—see our free catalog for details.*

Moon Filters

Cuts 87% of the light from the Moon. Reduces glare by uniformly reducing light transmitted over the entire spectrum.

.965" #5664, 1.25" #5662 **$ call**

Color Eyepiece Filters

Highest quality precision-ground optical glass. Fully anti-reflective coated. Solar system observations are dramatically improved. Thread into the barrel of any standard eyepiece, or directly into a universal camera adapter.

.965" Basic Set of 4 Filters #80A Blue, #58 Green, #25 Red, #15 Yellow.
#5510 **$ call**

1.25" Basic Set of 4 *#80A Blue, #58 Green, #25 Red, #15 Yellow.* #5514
1.25" Expansion Set of 4 *#21 Orange, #47 Violet, #11 Yellow-Green, #82A Very Pale Blue.* #5516
1.25" Advanced Set of 4 *#8 Light Yellow, #23A Light Red, #38A Deep Blue, #56 Light Green.* #5570
$ call

Deluxe Set of 8 Filters for 1.25" Includes all the filters in our basic and expansion filter sets.
#5517 **$ call**

Full Set of 12 Filters for 1.25" Includes Basic Set, Expansion Set, Advanced Set.
#5575 **$ call**

2" Set of 4 Includes #80A Blue, #58 Green, #21 Orange and #12 Yellow.
#5513 **$ call**

Individual .965", 1.25" & 2" Filters- Many colors available, see our catalog for details.

SkyGlow™ Light Pollution Filters

Enhance your viewing of faint deep sky objects with the best broadband light pollution filter you can buy. Our SkyGlow absorbs frequencies emitted by city lights, allowing transmission of the rest of the visible spectrum, yielding dramatic results.

SkyGlow Broadband Filters—Photographic and Visual
For use in slight to moderately light polluted areas.

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#5660 **$ call**

SC Broadband Filter–fits rear cell of Meade & Celestron SC scopes.
#5658 **$ call**

52mm Broadband Filter–For 52mm camera lenses, (Adapter rings available for other diameters.)
#5668 **$ call**

2.0" Broadband Filter–fits 2" eyepieces.
#5659 **$ call**

.965" Broadband Filter–fits .965" eyepieces.
#5661 **$ call**

SkyGlow UltraBlock Filters–Visual Only
For severely light polluted areas and faint nebulae.

1.25" UltraBlock Filter–fits 1.25" eyepieces.
#5654 **$ call**

SC UltraBlock Filter–fits rear cell of Meade & Celestron SC scopes.
#5656 **$ call**

Eyepieces & Barlows

NEW! 40mm Sirius Plossl! See catalog for details.

✧ Sirius™ Plössl 1.25" Eyepieces

Fantastic Name-Brand Quality Eyepieces at an Incredible Low Price!

You could pay nearly twice the price for 'famous name' Plössl eyepieces, but we don't think you'll be able to tell the difference if you compare them to these fantastic eyepieces!

Sirius Plössls are top-quality, 50° apparent field eyepieces with extremely sharp images of impressively high contrast. Ideal for all types of reflector, refractor and catadioptric telescopes. The Plössl design is renowned for its fantastic performance and has in recent years become the standard by which all other eyepieces are compared.

Each eyepiece is of the classic 4-element Plössl design. Every air-to-glass surface is fully Magnesium Fluoride anti-reflection coated. All lens edges are blackened in the same way as expensive military optics, to further eliminate any scattering of stray light and to maximize contrast.

The optics are mounted in precision black anodized aluminum housings with chrome-plated brass 1.25" barrels for durability and precision fit.

We guarantee you'll be impressed with the performance of the Sirius Plössls, even when compared to the more expensive name-brand Plössls.

25mm #8530, *17mm* #8531, *10mm* #8532, *7.5mm* #8533 **$ call**

Call for information on special package deals!

Any 2 *$ call*
Any 3 *$ call*
All 4 *$ call*

Case only #5911 ***$ call***

Explorer .965" & 1.25" Eyepieces

These fine quality multi-coated eyepieces offer great performance at Orion's low direct-discount price. Three different optical designs are incorporated, to maximize efficiency in the various focal lengths. Black anodized, internally blackened, threaded for filters (except 40mm .965").

.965 Orthoscopic
5mm #8580, **7mm** #8581, **9mm** #8582, **12.5mm** #8583 **$ call**

.965 Kellner
18mm #8584, **25mm** #8585 **$ call**

.965 Achromatic Huygenian
40mm #8586 **$ call**

1.25" Orthoscopic
5mm #8500, **7mm** #8502, **9mm** #8504, **12.5mm** #8506, **18mm** #8524, **25mm** #8526 **$ call**

1.25" Kellner
6mm #8536, **9mm** #8538, **12mm** #8540, **18mm** #8508, **25mm** #8510, **40mm** #8512 **$ call**

Superb Ultrascopic™ Eyepieces

Unlike other premium eyepieces, Orion Ultrascopics offer complete multi-layer coatings on ALL surfaces, for superior light transmission and contrast. Modern 5- and 7- element designs for pinpoint star images and breathtaking detail. Wide 52° field of view. Guaranteed to beat other brands selling for much more! Unsurpassed high-performance design!

Medium-High Power 5-element
20mm #8566, **15mm** #8568, **10mm** #8570, **7.5mm** #8572 **$ call**

Wide Field 5-element
25mm #8564 **$ call**
30mm #8562 **$ call**
35mm #8560 **$ call**

High Power 7-element *—Long Eye Relief*
5mm #8574, **3.8mm** #8576 **$ call**

MegaVista 1.25" & 2" Eyepieces

These outstanding eyepieces feature a 7-element design and incredibly sharp, fully multi-coated optics. The long eye relief and integral rubber eyeguards make these ideal for eyeglass wearers. The extra wide field of view (67°-70°) provides stunning images, perfect for deep space observing.

10.5mm 1.25" #8552 **$ call**
16.8mm 1.25" #8554 **$ call**
34mm 2" #8587 **$ call**
40mm 2" #8588 **$ call**

Illuminated Reticle Eyepieces

Orion offers 4 versions of the illuminated reticle eyepiece, a necessity for long exposure astrophotography and very useful for polar alignment. All have 1.25" barrels.

12.5mm Plossl Illuminated Reticle
Illuminator has fully adjustable brightness. Features double crossline reticle. Batteries included.
#8484 **$ call**

12mm Kellner Illuminated Reticle
Features double crossline reticle and red LED illuminator. Plugs into power panel drive bases.
#8482 **$ call**

9mm Orthoscopic Illuminated Reticle
Adjustable brightness illuminator. 'Bull's-eye within crosshairs' reticle. Needs 2 SR-44 batteries, not included.
#8488 **$ call**

12mm Kellner Illuminated Reticle
Same as 8482 above except has a wireless illuminator. Needs 2 SR-44 batteries, not included.
#8481 **$ call**

SR-44 Batteries #2360 **$ call**

UltraZoom™ 7–21mm

The finest zoom you can buy for your 1.25" telescope. For astronomy or terrestrial observing. 65°-35° field. Fully coated.

#8556 **$ call**

See our free catalog for a fantastic selection of name-brand eyepieces!

CELESTRON TeleVue

Barlow Lenses

Orion offers a large selection of barlow lenses, allowing you to double or even triple the power of your eyepieces, maximizing the versatility of your collection. Available in .965", 1.25" and 2" diameters.

Fully Baffled 2x Barlow
Multi-coated, with internal baffling to block transmission of stray light. Premium performance at a remarkable price.
.965" #8740 **$ call**
1.25" #8746 **$ call**
2" #8724 **$ call**

Ultrascopic 2x Fully Multi-Coated Barlow
3-element Ultrascopic lens for superior images and precise color correction. Fully multi-coated optics, black anodized barrel. 1.25 barrel.
#8750 **$ call**

VariPower 2-3x Barlow
Allows you to adjust the magnification factor of the barlow by sliding the internal cell along a calibrated scale. Fully multi-coated optics. 1.25" barrel.
#8748 **$ call**

Shorty Barlows

The short bodies allow extra versatility: provides 2x magnification when the eyepiece is inserted directly, and 3x magnification when positioned before the diagonal on a refractor or SC. Will work in all telescopes, including those where longer barlows won't work.

.965" #8710 **$ call**
1.25" #8711 **$ call**

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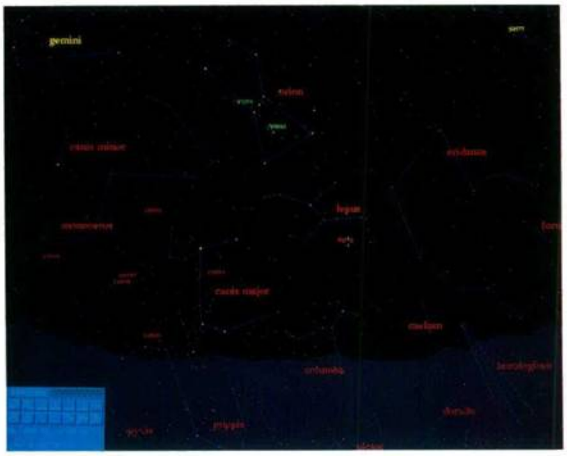
ASTROBYTES

View Distant Suns



ASTRONOMY: Darla Evans

Distant Suns for the Macintosh (version 2.0)

Virtual Reality, 2341 Ganador Court, San Luis Obispo, CA 93401, (800) 829-8754. Price: $99.95 for disk version; $149.95 for CD-ROM version. Minimum requirements: Macintosh, 2 MB of memory, hard disk with 3.5 MB of free space, System 6.0.2 or 7.X, and QuickTime (to view movie clips). Recommended: Macintosh II, math coprocessor, and color monitor. Extended star catalogs available as option for disk version.

Virtual Reality has converted its PC-based planetarium program for the Mac in two flavors, a disk version and a CD-ROM version, while retaining its emphasis on images (over 1,500 images in the CD-ROM version). In fact, with QuickTime you can view movie clips such as Ranger 9's impact on the Moon provided with the disk version. The CD-ROM version includes 30 other clips and adds sound effects when you click on the planets, stars, and deep-sky objects.

You can view the constellations, find the positions of the planets, and print star charts to help you locate deep-sky objects with your telescope. A skylight function lets you reproduce light-polluted city skies or dark country skies. Tired of viewing the solar system from Earth? You can change your viewpoint to anywhere within the solar system. The program computes the periodic change in Earth's orbit, called *precession, so you can plot positions from* 4713 B.C. to A.D. 9999.

The disk version provides you with 9,824 stars down to magnitude 6.7 and about 2,000 deep-sky objects from Messier's catalog and the *New General Catalogue*. The CD-ROM version extends the star database to over 255,000 stars down to magnitude 8.6 (available as an option for disk version users) and also provides the Hubble *Guide Star Catalog*, which adds another 15 million stars down to 15th magnitude.

A control pad contains a set of buttons for zooming in and out, finding the Sun and Moon, turning object names on and off, and showing quick views of the northern, eastern, western, and southern skies. If you don't like these functions, you can customize the panel by selecting up to 24 of 40 button codes or by defining nine of your own buttons.

Distant Suns includes some features designed especially for observers: a lunar phase diagram, a reticle for checking an object's position in a scope's finderscope or eyepiece, a What's Up function that shows which planets are visible, and a planning guide that will print out the stars, nebulae, or galaxies visible at a time you specify.

A few glitches make these less helpful than they could be otherwise. The lunar phase diagram shows a line from 0 (New Moon) through 0.5 (Full Moon) to 1 (New Moon). This line really plots the Moon's age, not the more helpful illumination or phase. The tabulated phase number seems to be correct, but the dates listed for New Moon seem to be rounded rather than truncated.

The reticle automatically changes size as you zoom in on an object. But it would be nice to be able to set the size of the reticle to represent the field of a finder or an eyepiece. It would also be helpful if the user could preview the planning guide list before printing it out or storing it as a file. That would enable observers to easily customize the list before an observing session.

Other improvements I'd like include entry of dates by keyboard rather than with up/down buttons that make it awkward to change dates by more than a few years. Virtual Reality also should fix improperly lower-cased names, such as "leo." It's hard enough for beginners to learn the sky and astronomical concepts without confusion over which names should be capitalized and which shouldn't.

Despite these growing pains, Distant Suns for the Macintosh is a good program for beginning observers and armchair astronomers. If you want lots of images, not to mention movie clips, the CD-ROM version should be a hit. — *Dave Bruning*

NEW SOFTWARE

Hidden Image (version 1.2c)

Sehgal Corporation, 4 Sayre Drive, Princeton, NJ 08540. Introductory price: $299.99 for Lynxx, ST-4, and Electrim version; $399.99 for standard version plus ST-6 and FITS support. Minimum requirements: 80386-based computer, math coprocessor, VGA display, hard drive, and a mouse. Recommended: 4 MB of memory for standard version and 8 MB for ST-6 version.

Sharpen your images with Hidden Image. It uses a sophisticated mathematical scheme called maximum entropy deconvolution to remove some effects of poor optics and atmospheric blurring from images, improving the resolution up to two or three times. The program uses two image frames so you can compare images before and after processing.

Hidden Image provides brightness stretching, cosmic ray removal, contrast adjustment, unsharp masking, and other image processing tools. You can combine several short-exposure CCD images to create an equivalent long-exposure image; a registration feature aids in aligning images. You can extract portions of a large image simply by scrolling around the image until you find the portion you wish to process. The program supports the following image file formats: TIFF, FITS, ST6, ST4, Electrim, LNX, and raw integer and floating point.

Gems of Hubble
Endeavour Views the Earth
Images of Mars
Magellan Highlights of Venus
Scientific Results from GHRS

Five Electronic PictureBooks produced by the Exploration in Education program of the Special Studies Offices at the Space Telescope Science Institute; distributed by the Astronomical Society of the Pacific, 390 Ashton Avenue, San Francisco, CA 94112, (415) 337-2624. Price — Gems of Hubble (two disks): $19.95; Endeavour Views the Earth (five disks): $39.95; Images of Mars (two disks): $19.95; Magellan Highlights of Venus (two disks): $19.95; and Scientific Results from GHRS (one disk): $9.95. Electronic PictureBooks require a color Macintosh with System 7.X, 2.5 MB of memory, and a hard disk. It includes HyperCard Player 2.1.

Electronic PictureBooks are multimedia presentations of color images, maps, informative text, and reference material intended for teachers, students, and armchair explorers. These HyperCard stacks allow you to access a wealth of images without the need of a CD-ROM drive and provide background material unavailable in other image collections. The Gems of Hubble *set also provides* 11 images in GIF format you can use with other programs. □

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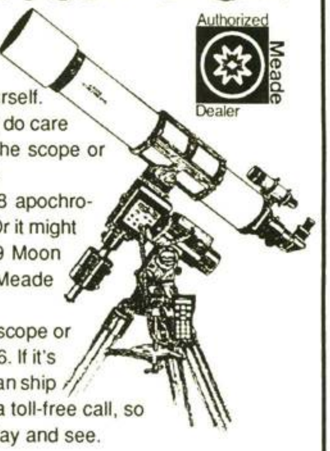

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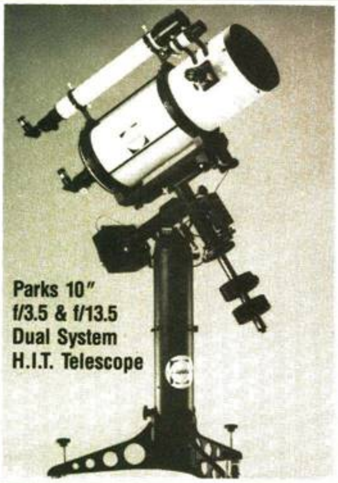

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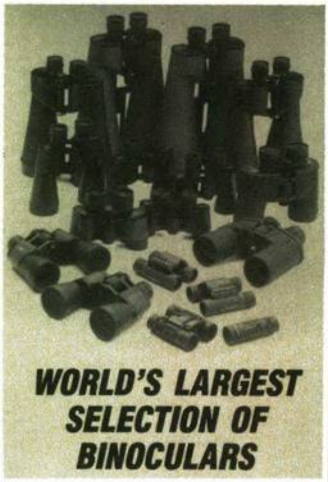

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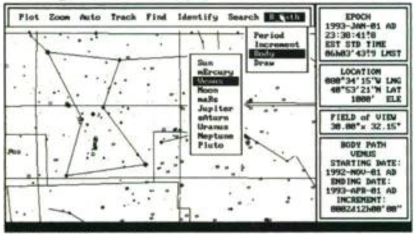

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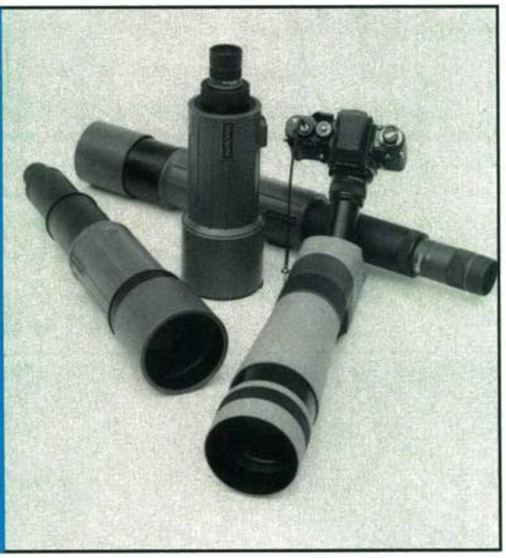
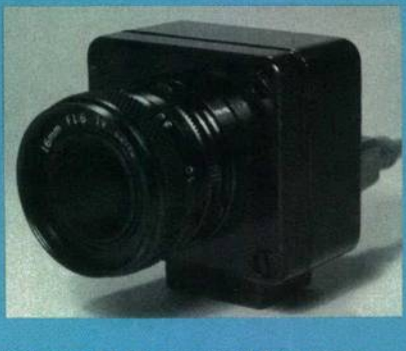
Europtik, Ltd., P.O. Box 319, Dunmore, PA 18512, (800) 873-5362, fax (717) 969-4330. 5x25: $410; 7x35: $440; 10x40: $475.



New Swarovski Spotting Scopes

The CT-75 and CT-85 (the numbers refer to the diameter of the front lens in millimeters) are extendable spotting scopes that collapse for transport. The AT-80 HD (with an angled eyepiece) and ST-80 HD (straight-through eyepiece) feature low-dispersion glass for improved color correction.

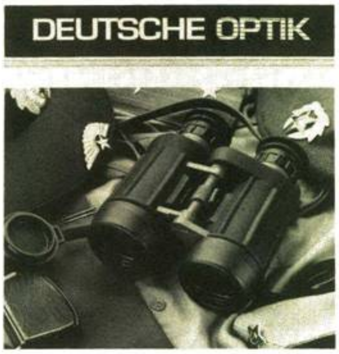
Swarovski Optik North America Ltd., One Wholesale Way, Cranston, RI 02920, (800) 426-3089. CT-75: $855; CT-85: $1,045; AT-80 HD: $1,045; ST-80 HD: $1,045. Eyepieces are extra on all models.



Electrim Color Imager Software

Electrim Corporation offers software for its EDC-1000C color CCD camera that supports the Video Electronics Standards Association extensions. You can use any Super VGA card that supports VESA extensions 1.2 and provides resolutions of 800 x 600 or 640 x 480 with 16-bit color.

Electrim Corporation, P.O. Box 2074, Princeton, NJ 08543, (609) 683-5546, fax (609) 683-5882. Call or write for information and prices.



Catalog of German Optics

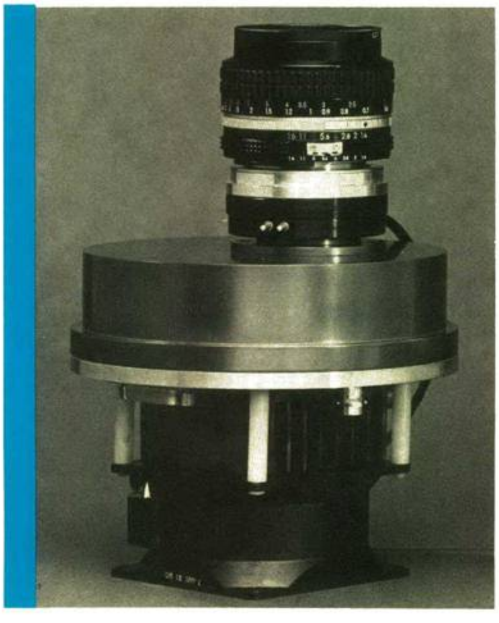
The Deutsche Optik catalog features optical instruments made by Carl Zeiss Jena in Germany, such as the 7x40 EDF Warsaw Pact Military binocular shown on the cover. The catalog includes other unique products and prices are said to be "unusually competitive." The catalog is free.

Sunset Cliffs Merchandising, P.O. Box 7518, San Diego, CA 92167, (800) 225-9407.

Equipment Cases for Air Travel

The Tenba Air Max (shown) is a lightweight attaché case for photo and telescope gear. The rigid, shock-absorbent construction is designed for shipment as airline luggage and meets Air Transport Association shipping standards. Air Max cases are available in four sizes. Also available: PAT 52 shipping case for tripods and telescope tubes.

Tenba, 503 Broadway, New York, NY 10012, (212) 966-1013, fax (212) 334-0841. Air Max cases: $338 to $378; PAT 52 tripod/tube case: $380. Call or write for catalog.



StarScape CCD Cameras

First Magnitude Corporation's newest CCD camera, the StarScape III (shown), uses the Loral/Fairchild CCD422 1024x1024 array with 15-micron-square pixels. The company also offers lower-cost StarScape II cameras with either Texas Instruments' TC215 1024x1024 or the TC217 1138x488 chips. The StarScape II cameras can be either liquid nitrogen or thermoelectrically cooled.

First Magnitude Corporation, 519 South Fifth Street, Laramie, WY 82070, (307) 745-3743, fax (307) 766-4026. Call or write for details.

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Flashlight Headbands

The Jakstrap (shown) is a flexible, adjustable headband that can hold AA-cell mini-flashlights, allowing users to work in the dark hands free. The Ultra Jakstrap also has a fleece lining. The System II models hold larger C-cell flashlights. The headbands are available in red, blue, green, and camouflage and are available through the Orion Telescope Center or directly from the manufacturer.

Kaleidascope, P.O. Box 58114, Salt Lake City, UT 84158, (801) 328-4407. Standard Jakstrap: $5.95; Ultra Jakstrap: $8.95; System II: $7.95.

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Wind and Weather, The Albion Street Water Tower, P.O. Box 2320, Mendocino, CA 95460, (800) 922-9463. Copenhagen Sundial: $240; Pedestal: $169; Suntracker Sundial: $200. Shipping extra. Write for free catalog of other products.

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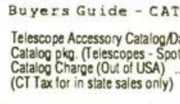

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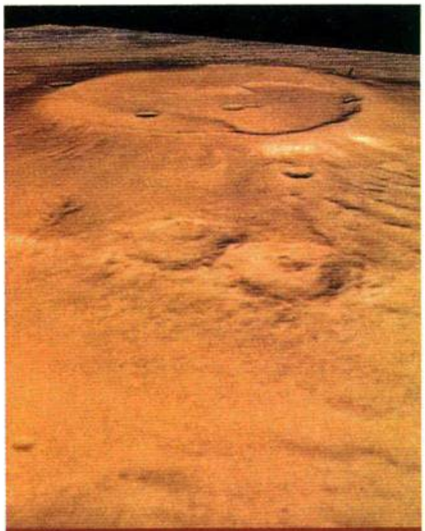

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READINGS & CREDITS

Hypergiants (page 32)

Stars by James B. Kaler, (Scientific American Library, 1992). General introduction to stars, spectra, and stellar evolution.

Stars and Their Spectra by James B. Kaler, (Cambridge University Press, 1989). A more detailed explanation of what stellar spectra tell us and how stars age.

Copernicus and Mare Insuluram (page 56)

The Moon: An Observing Guide for Small Backyard Telescopes by Michael T. Kitt, (Kalmbach, 1992). The most up-to-date guide to viewing the Moon.

Geology of Multi-Ring Impact Basins by Paul Spudis (Cambridge University Press, 1993). A picture-rich examination of these large, important planetary features. Summarizes much lunar geology of the past 20 years.

Taking the Deep-Sky Plunge (page 58)

The Observer's Sky Atlas by Erich Karkoschka, (Springer-Verlag, 1990) A handy pocket-sized book with close-up charts for deep-sky objects.

Visual Astronomy of the Deep Sky by Roger Clark (Cambridge University Press, 1990) A detailed look at the eye and observing techniques.

Virtual Sky (page 70)

"The Digital Darkroom" by Richard Berry, ASTRONOMY, March and April 1993. A pair of how-to articles that introduce the basics.

Introduction to Astronomical Image Processing by Richard Berry (Willmann-Bell, 1991). The basics, in more detail, together with software that starts you off in processing images.

Choosing and Using a CCD Camera by Richard Berry (Willmann-Bell, 1992). A guide to selecting the right camera; includes software for calibrating images.

Cover: NASA; **p. 4-5:** Contents; **p. 18:** Richard Griffiths/Johns Hopkins University and NASA; **p. 20:** Martin Marietta; **p. 22, top:** CARA; bottom: NOAO; **p. 24, left:** ESA; **right:** Larry Webster, courtesy of the Mount Wilson Observatory Association; **pp. 26-31:** NASA; **pp. 32-33:** © Anglo-Australian Telescope Board; **p. 34**: Jack Marling; **p. 35:** illustration by Phil Kirchmeier; **p. 36:** Robert Kennicutt; **p. 37:** Anglo-Australian Telescope Board; **pp. 38-39:** Anglo-Australian Telescope Board; **pp. 39-44:** all diagrams Phil Kirchmeier after Jay Gallagher; **p. 42:** Anglo-Australian Telescope Board; **pp. 44-45:** Canada-France-Hawaii Telescope; Galaxies; **p. 49:** Terence Dickinson; **p. 50:** Martin C. Germano; **p. 51:** Keith Ward; **p. 56:** Lick Observatory; **p. 57:** Christian Vladrich; **p. 58, bottom left:** Jack Newton, 20-inch f/5 Newtonian, cold camera, film and exposure unknown; **top right:** Luke Dodd, 300mm f/4 lens, 10 minutes on hypered Fujicolor 400; **bottom right:** Mansfield Clinnick, 8-inch f/4 Newtonian w/coma corrector, 15 minutes on Ektar 1000; **p. 59, top left:** Jack Newton, 20-inch f/5 Newtonian, cold camera, film and exposure unknown; **middle left:** Larry Myers, 11-inch SCT at f/6.3, 35 minutes on hypered Konica 1600, **top right:** Franz Klauser, 740mm f/4 lens, 70 minutes on hypered Kodak Tech Pan with Deep Sky filter; **bottom right:** Bob Luffel, 14-inch SCT at f/7, 30 minutes on hypered Konica SR400; **p. 61:** Jack Marling, 36-inch f/10 telescope, Fujichrome 400 film, 1-hour exposure; **pp. 62-63:** Steven G. Davis; **p. 64:** Jack Marling, 17.5-inch f/4.5 telescope, Fujichrome 400 film, 30-minute exposure; **p. 64:** Bill Iburg, 14-inch f/5.5 SCT, Ektachrome 400 film, 25-minute exposure; **pp. 66-69:** All equipment photographs by Chris Becker; **p. 70:** Jack Newton; **p. 71, top:** Nik Szymanec; **bottom left:** Keith Snyder; **bottom right:** Jack Newton; **p. 72, top:** George Fowler; **bottom:** James Edlin; **p. 73, top:** James Edlin; **bottom left:** Greg Terrance; **p. 74, top:** Jack Newton; **middle:** Jack Newton; **bottom:** Jack Newton; **p. 75, top:** Michael Borman; **bottom:** Bob Elliot; **p. 76, top:** Jack Newton; **middle:** Ian King and Nik Szymanek; **p. 77, top and bottom:** Jack Newton; **p. 81, top:** Timothy Printy, 28mm f/4 lens with 0.42x fisheye adapter, Fuji Super HG 400 film, 30-minute exposure; **bottom:** Chris Dunmill, 35mm lens at f/3.5, Fujichrome 100 film, 5-minute exposure; **p. 82, top left:** James R. Foster, Michael A. Stecker, and William Fletcher, 14-inch SCT at f/7, composite image of hypersensitized Tech Pan exposures: 156 minutes (Lumicon Hi-Performance filter); 84 minutes (Wratten #11 filter); and 90 minutes (Wratten #23A filter); **bottom left:** Andre Bormanis, 35mm lens at f/3.5, Ektachrome 800 film, 6-second exposure on December 9, 1992; **top right:** Lin Ben Chu, Takahasi FC 100 telescope, Vericolor HC film, 1/250-second exposure on November 6, 1993, from Taiwan City, Taiwan; **bottom right:** Gerald Rhemann, 8-inch Schmidt camera, composite of one 6-minute and one 7-minute exposure on October 10, 1993; **p. 83:** George Greaney, 6-inch f/7.1 apochromatic refractor, hypersensitized Fuji Super HG 400 film, composite of two 50-minute exposures; **p. 92:** Darla Evans; **p. 100:** Mark Robinson/University of Hawaii. ☐

MEETINGS & EVENTS

February 12
Winter Star Party, Portsmouth Campus, Tidewater Community College, Virginia. Contact R. H. Stewart, 1064 Dune Street, Norfolk, VA 23503, (804) 583-9397.

March 5
Astroimage 94, California State University, Fullerton, California. Contact John Sanford, 2195 Raleigh Avenue, Costa Mesa, CA 92627, (714) 722-7900. Submit papers to Wayne Johnson at the same address, (714) 646-7578.

March 14-18
25th Lunar and Planetary Science Conference, NASA Johnson Space Center, Houston, Texas. Contact LeBecca Simmons, LPI Publications and Program Services Department, 3600 Bay Area Boulevard, Houston, TX 77058, (713) 486-2158.

March 18-20
The Gathering at the Equinox, Museum of York County, Rock Hill, South Carolina. Contact Barbara or Glenn (803) 329-2121.

April 7-10
First Annual Peach State Star Gaze, near Covington, Georgia. Contact Ken Poshedly, 3440 Everson Bay Court, Snellville, GA 30278, (404) 979-9842.

April 7-10
Mid-South Star Gaze, Rainwater Observatory, French Camp, Mississippi. Contact James Hill, FCA, French Camp, MS 39745, (601) 547-6865 or (601) 547-6970.

May 5-11
1994 South Pacific Star Party, Sydney, Australia. Contact Treasurer, Astronomical Society of N.S.W. Inc., P.O. Box 1093, Darlinghurst, N.S.W. 2010 Australia.

June 25-26
Universe 94, Northern Arizona University, Flagstaff Arizona. Contact the Astronomical Society of the Pacific, (415) 337-1100. ☐

Clubs, please submit announcements at least four months prior to your event. Readers, include a self-addressed, legal-sized envelope with your request for information.

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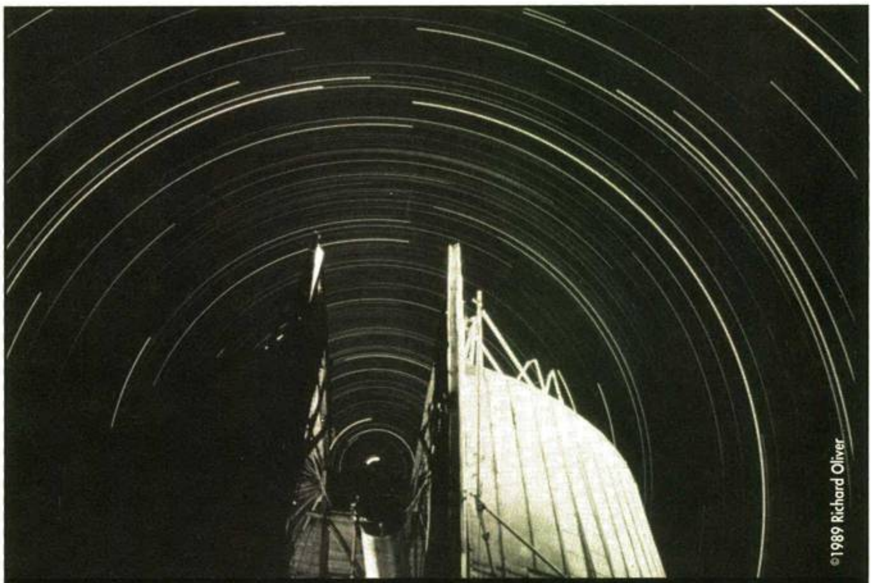

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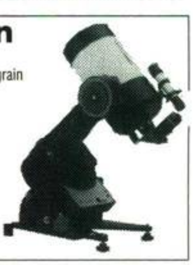

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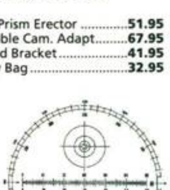

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Pro-Optic Slow Motion Control **39⁹⁵**

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EXPERIENCE

ASTRONOMY MAGAZINE
REVIEWS
GENESIS-SDF

Excerpts from Alan Dyer's review in the January '94 issue:

"The newest version of Tele Vue's Genesis refractor offers first-class optics in a convenient and highly portable package...

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...On critical star tests, the Genesis-sdf performed flawlessly. Both pairs of the double-double star Epsilon Lyrae appeared cleanly split with dark sky between the tiny, sharply defined stars. Saturn was sharp and contrasty, with the Cassini division in the rings as well as color differences in the belts and zones on the planet's disk clearly visible.

The level of color correction in the SDF was impressive. The edge of the Moon was pure white. Saturn appeared without any trace of a blue halo. The zero magnitude star Vega, one of the toughest tests, showed the merest hint of a blue halo that came and went with seeing conditions. This is a superb level of color correction in any refractor, let alone one this fast and portable.

The flat field was apparent when scanning star field with Tele Vue's 35mm Panoptic eyepiece, itself optimized to provide a wide, flat field.

Combined with premium wide-angle eyepieces, this is a telescope capable of providing stunning low-power views of Milky Way starfields. And yet under good seeing conditions, the sharp optics will easily handle 200 to 250 power for crisp lunar and planetary views.

Genesis serves as a superb deep-sky astrophoto scope. Test shots on 35mm film of starfields in Cygnus exhibited sharp star images corner to corner across a 4° field.

The rack-and-pinion focuser operated smoothly with no backlash or image shift. The focuser accommodates 2-inch accessories and has a screw for tightening the tension. The focuser did not slip even with heavy cameras or eyepieces attached.

I tested the Genesis on Tele Vue's alt-azimuth mount, the Gibraltar, a well-crafted mount made of machined and black-anodized aluminum. The wood tripod is made of ash. The mount has smooth Dobsonian-like motions, making it easy to nudge this scope every few moments to recenter the image.

Tele Vue offers a finder called the Starbeam. When you look through this nifty device, you see a red dot projected against the naked-eye sky. The dot shows you exactly where the scope is pointed.

I also checked out Tele Vue's new Air-Chair seat, a sturdy, well-padded stool with a handy pneumatic height adjustment. Whether you are looking at the horizon or at the zenith, you can remain comfortably seated without the need to stretch or crouch, a convenience that adds immeasurably to the pleasure of using this telescope.

In all, I found the package well engineered and friendly to use. If a portable, high-performance, and beautifully finished instrument is what you are seeking in an astronomical telescope, the Genesis-sdf is an excellent choice."

TELE VUE REFRACTORS

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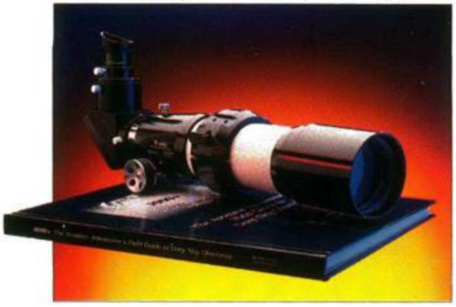


No picture or description prepared me for the beauty of the design or the excellence of the workmanship. J.T. - RI

The detail it shows on Jupiter is absolutely unbelievable. B.D. - CO

I was able to see Jovian lunar shadow transit easily with this instrument. I love the design and features - I may have to buy a Genesis! R.G. - PA

It's almost as if I'm not using a scope at all. Too many scopes just get in the way and make observing a frustrating experience. T.Z. - NY

Wanted a first telescope with superior optics, portability and value. I got what I asked for, wonderful little thing. J.P. - U.K.

Well done! Saw the Owl and M108 in same field. T.J. - KS

The Genesis-sdf, 20mm Nagler Type 2, and Gibraltar mount combination is a game breaking touchdown! G.B. - NJ

Compact, easy to carry & solid case. Delivers one of the best, false-colour-free images I've ever seen in this size & aperture! Thank you. B.D. - Germany

WOW! Easily split Nu Scorpii and Antares! Jupiter looks great ! D.S. OH

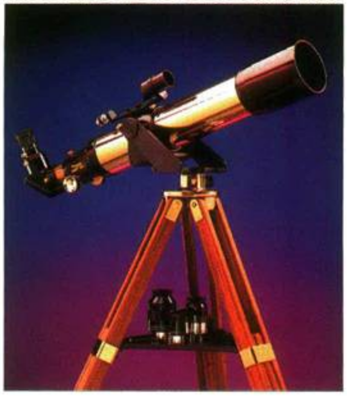
I am greatly satisfied with the quality of craftsmanship that was put into this fine instrument. M.H. - PA

Fantastic! Sharp views of planets, moon and star fields...excellent high power results!! J.C. NJ

It's the only scope I recommend to friends. B.H. - KS

Superb optics! Sharpest images of any scope I've ever owned. Pinpoint star images. R.M. MD

Renaissance-SDF: Solid Brass



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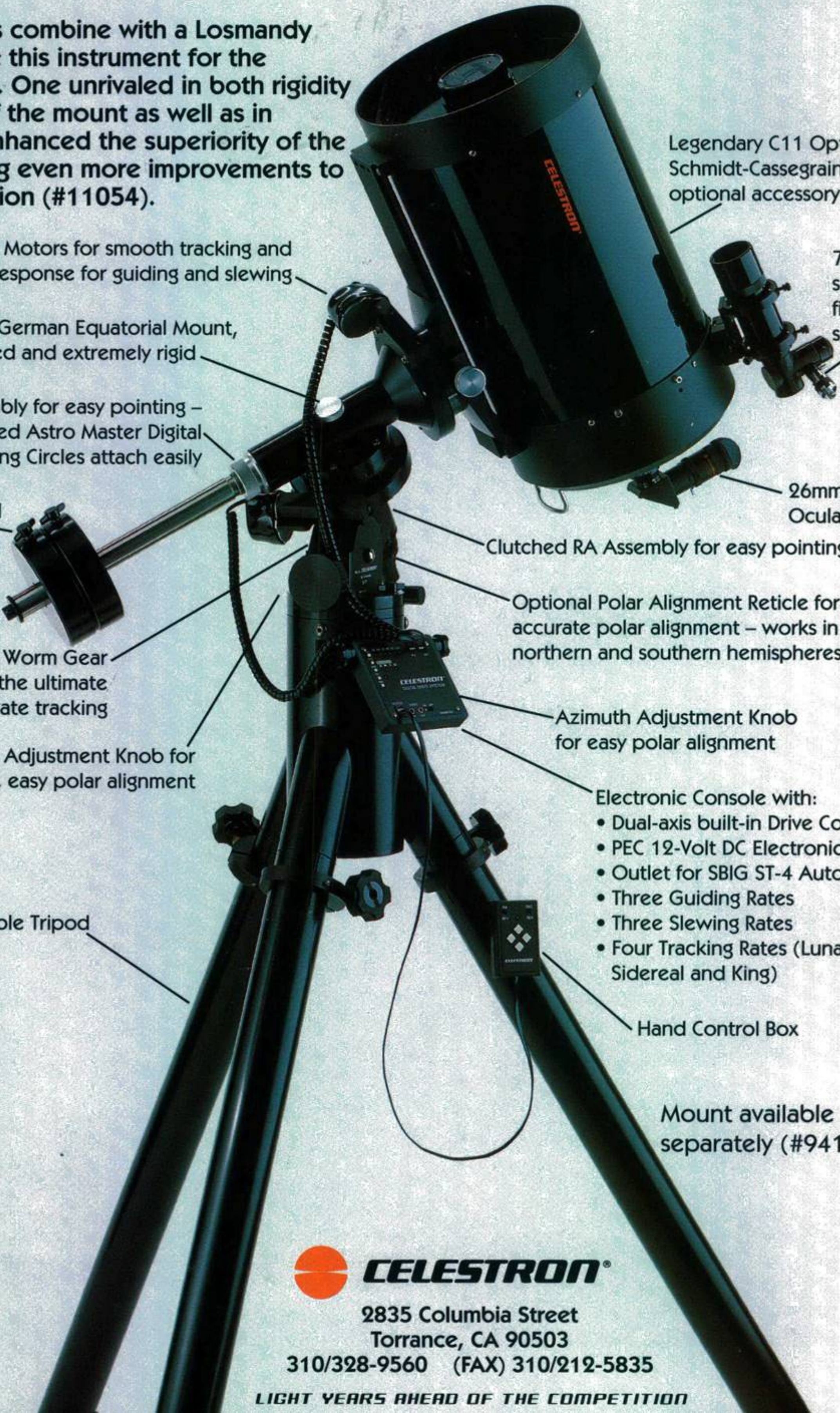

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